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Framework Assessment and 2013 Update using a Stage-based Population Model for Spiny Dogfish (*Squalus acanthias*) in the Northwest Atlantic

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

A stage-based migration model of population dynamics, with abundances aggregated into region, season, sex and maturity stages, was developed to represent the transboundary (US and Canada) population of dogfish occurring throughout waters of the Gulf of Maine, Bay of Fundy, and Scotian Shelf. The model also facilitates estimation of independent stock abundance models by region, by disabling migration parameters, but this was found to under-estimate stock abundance in Canadian waters. Simulation studies with the model were used to investigate reference point candidates for gauging stock status. Adult female abundance (SSN) and exploitation (Fssnmsy) stood out as the most critical aspects of the population to monitor. Projections of various exploitation scenarios were used to estimate consequences of harvest strategies relative to these reference points.

The framework model terminated in 2010, as there is no detailed length composition data for US catch and survey sampling in more recent years. Several approaches to update stock status to 2013 were investigated. The option chosen was to treat available summary estimates of US catch and population biomass as relative adjustments to those of earlier years. Assumptions about size compositions, especially those of the commercial catch, were required to accomplish this. The population had been declining from 1992 to 2007, possibly having exceeded its carrying capacity as fisheries could not account for the drop. Since 2007, the population has been growing, and in 2013, was estimated to be 789.2 million. This is 95.5% of the assumed abundance at maximum sustainable yield (Amsy) of 819.7 million. The carrying capacity is currently assumed to be the maximum estimated population size seen in the historical time series.

Évaluation du cadre et mise à jour de 2013 selon un modèle de population axé sur les étapes pour l'aiguillat commun (*Squalus acanthias*) dans l'Atlantique Nord-Ouest

RÉSUMÉ

Un modèle de migration de la dynamique des populations axé sur les étapes, avec les abondances regroupées par région, saison, sexe et étape de maturité, a été élaboré pour représenter la population transfrontalière (États-Unis et Canada) de l'aiguillat commun qui se trouve dans les eaux du golfe du Maine, de la baie de Fundy et du plateau néo-écossais. Le modèle facilite aussi l'estimation des modèles indépendants de l'abondance des stocks par région en désactivant les paramètres de migration, mais on a découvert que cela entraîne une sous-estimation de l'abondance des stocks dans les eaux canadiennes. Des études de simulation avec le modèle ont été utilisées pour étudier les points de référence éventuels pour mesurer l'état du stock. L'abondance des femelles adultes (ESR) et l'exploitation (Fesrrms) sont ressorties comme les principaux aspects de la population devant faire l'objet d'une surveillance. Les prévisions de divers scénarios d'exploitation ont été utilisées pour estimer les conséquences des stratégies de pêche par rapport à ces points de référence.

Le modèle de cadre a pris fin en 2010, car il n'y a aucune donnée détaillée sur la composition selon la longueur pour les prises aux États-Unis et aucune donnée sur l'échantillonnage lors des relevés au cours d'années plus récentes. Plusieurs approches pour la mise en jour de l'état du stock en 2013 ont été étudiées. L'option choisie a été de considérer les estimations sommaires disponibles des prises aux États-Unis et de la biomasse de la population comme des ajustements relatifs à celles des années précédentes. À cette fin, des hypothèses sur les compositions selon la taille, surtout celles des prises commerciales, étaient nécessaires. La population a subi un déclin de 1992 à 2007, peut-être parce qu'elle avait dépassé sa capacité biotique, étant donné que les pêches ne pouvaient pas expliquer la chute. Depuis 2007, la population est en augmentation, et elle a été estimée à 789,2 millions d'individus en 2013. Il s'agit de 95,5 % de l'abondance présumée au rendement maximal soutenu (Mrms) de 819,7 millions d'individus. On suppose que la capacité biotique actuelle est l'effectif de population estimé maximal qui a été observé dans la série chronologique historique.

INTRODUCTION

The Spiny Dogfish (*Squalus acanthias*) is a small cold-temperate shark found in waters throughout the Northwest Atlantic, with large numbers occurring between North Carolina and southern Newfoundland. Their distribution shifts seasonally as many migrate south in winter and north in summer, with the Gulf of Maine roughly corresponding to a centre of distribution overall. This means that the population occurs in seasonally-varying proportions in both US and Canadian waters. Most Atlantic Canadian landings of Spiny Dogfish are taken in directed handline, longline, and gillnet fisheries. Catches were unrestricted prior to 2002. Since 2002, precautionary directed catch quotas based on past catches have been in place for the Fisheries and Oceans Canada (DFO) Maritimes Region. The quota since 2004 has been set at 2500 metric tonnes (mt). Quotas to this point have not been based on scientific advice, and there are no restrictions on discarding or bycatch in other fisheries. In 2003, an intensive 5-year research program on Canadian dogfish was initiated by DFO, conducted in cooperation with the dogfish fishing industry through a Joint Project Agreement (JPA). The JPA provided for the collection of large numbers of at-sea and landed samples of dogfish catches that were used in analyses of commercial catches and dogfish biology.

Campana et al. (2007) presented an overview of all available information on the stock structure, migration patterns, abundance trends and status of the Canadian portion of the Atlantic Spiny Dogfish population. In 2010, as part of a joint Canadian-US stock assessment, attempts were made by scientists in both countries to model the entire North West Atlantic population (TRAC 2010). Both of the models that were tabled had significant shortcomings, with a US model failing to take stock mixing into account and a Canadian model failing to provide simulation testing and reference points. As a result, the US elected to meet its domestic management requirements by proceeding with a US-only stock assessment. Canada decided to complete the population-level assessment by refining and testing the population model. This led to development of a stage-based model, representing population components by sex and maturity stages rather than detailed length compositions. The results of the stage-based model, showing the status of the entire North West Atlantic Spiny Dogfish stock, forms the basis of the current stock assessment, which is tabled here. Simpler models were also attempted, of which a surplus production model and a time-varying-Q Virtual Population Analysis (VPA) model are discussed, as they represent approaches that are independent of the Transboundary Resources Assessment Committee (TRAC) and stage-based models that provided some insights.

The stage-based model was used to conduct simulations to estimate the likely consequences of various exploitation scenarios on stock status, which provided a foundation for deriving reference points for Spiny Dogfish. The reference points are then used to gauge historical and projected stock status.

DOGFISH MODEL

The proposed model developed for Atlantic Spiny Dogfish is a forward-projecting stage-based (juveniles and adults; males and females), spatially explicit (two regions: Canada and US) population dynamics model with two time steps (November-April and May-October) in each year. All US East Coast waters are included in the US zone. The Canadian zone is defined as the eastern waters of the Gulf of Maine, the Bay of Fundy and the Scotian Shelf (Northwest Atlantic Fisheries Organization (NAFO) Divisions 4VWX5YZ), comprising the largest proportion of dogfish in Canadian waters (Campana et al. 2007). Dogfish stock components in the Gulf of St Lawrence and Newfoundland are not included. Figure 1 provides a generalized view of dogfish distribution in the Northwest Atlantic.

Population components are observed by the US Spring Research Vessel (RV) survey (1968-2010) and Canadian Summer RV survey (1970-2010). Fishing mortalities by component are observed by Commercial Landings + Dead Discards (1922-2010). The model predicts the population components via recruitment, transition between juvenile and adult stages (theta), migrations between US and Canadian waters, natural mortality, and fishing mortality.

Approaches to updating the assessment through 2013, in the absence of US source data, are also explored.

POPULATION DYNAMICS

The population is comprised of fish that have two invariant characteristics: their sex and their home region. Home regions are defined as the region in which a fish was born. Beyond this, the model tracks fish by year, time step, region currently occupied, sex and maturity stage.

Annual Cycle

Within a time step, the sequence of events is fixed: transfers from juvenile to adult maturity stages; migration; fishing and natural mortality. Recruitment and survey fits occur between the time steps.

Detailed sequence of events:

Time-step 1 (November-April):

Growth
Canada to US migration
Fishing and Natural Mortality
Recruitment
US Spring RV survey fit

Time-step 2 (May – October):

Growth
US to Canada migration
Canada Summer RV survey fit
Fishery and Natural Mortality

Growth and Maturity

Growth is modelled with a two parameter von Bertalanffy relationship. For Canadian Spiny Dogfish, growth equations were fitted to length-age data assuming a length at age 0 of 30 cm total length (TL) (25 cm fork length (FL)) (Campana et al. 2009), and updated with additional data in 2012.

$$L_a = L_\infty - (L_\infty . L_0)e^{-Ka}$$

Sex	L_∞	K	L_0
Males (TL)	83.0	0.126	30.35
Females (TL)	106.0	0.066	30.35

Parameter estimates for the US growth curve (Nammack et al. 1985) are:

Sex	L_∞	K	L_0
Males (TL)	82.5	0.148	30.35
Females (TL)	100.5	0.106	30.35

For Canadian dogfish (Campana et al. 2009), length at 50% maturity is 72.5 cm FL (82.1 cm TL) for females and 55.5 cm FL (63.6 cm TL) for males. The logistic functions, re-formulated for TL, are:

Female proportion mature = 1/(1+exp(-(-18.75+(0.23*TL))))

Male proportion mature = 1/(1+exp(-(-15.09+(0.238*TL))))

Equations for proportion mature at length of US dogfish were reported in Nammack et al. (1985), although they made use of an arcsine function in a manner that could not be duplicated here. It is possible Nammack et al. (1985) used a package implementing an arcsine transformation for binomial proportions, common in the 1980s, which was not equivalent to applying an arcsine function as indicated. In the analysis presented herein, the authors attempted to use visual estimates of the proportion mature at length of US dogfish from graphs presented in Nammack et al. (1985), although this produced very narrow transition length ranges compared to more recent methods for estimating maturity ogives, and this significantly worsened model fits. Instead, a proxy tactic was used to modify the Canadian maturity equation coefficients to replicate the L50s of Nammack et al. (1985). The resulting coefficients were 0.24 for females and 0.254 for males. The L50s are believed to be valid, although this approach imposes the intercepts of the Canadian equations on the US dogfish.

The growth and maturity equations were applied to survey abundances at length to derive deterministic abundances by maturity stage (adjustable in the model for catchability by sex and stage) and compute annual maturity (juvenile-to-adult) transition thetas. These are treated as observed values. These thetas would be valid provided the relative proportions at length (in the length composition data) within the juvenile blocks are appropriate, there are no temporal variations in maturity at length, and the growth equations are appropriate. These are weak assumptions due to juvenile catchability issues and the ad hoc derivation of the growth equation for US dogfish. Young juveniles tend to favour pelagic habitat, especially for the first six (male) or ten (female) years, making catchability in the RV surveys very low. Recognized trends in maturity at length occur (Sosebee 2005), and these are likely confused by geographic variations. In addition, the Canadian-derived intercept for the US growth equation may be too large given that US (southerly) dogfish mature younger and smaller than Canadian (northerly) dogfish, such that the lower portion of the von Bertalanffy curve may be shifted too high at lengths of first maturity. These issues were addressed by fitting predicted thetas to the observed (deterministic) thetas with large error assumptions (log standard deviations (SD) of 0.6).

During a framework review in February 2014, it was decided to use US maturity estimates for both US and Canadian components of the Spiny Dogfish population.

Pupping

Observed annual pupping rates are computed as a function of the proportion of females mature at length and the number of pups produced at length. Information on pupping rates is taken from Campana et al. (2009), which is based on dogfish samples collected in Canadian waters between 2002 and 2005.

The estimated number of pups produced, as a function of female length (FL) is:

$$\text{Free embryos} = 9.8 - 0.0053(FL)^2 + 0.000056(FL)^3$$

Reformulated as a function of TL the relationship is:

$$\text{Free embryos} = 9.8079 - 0.00477(TL)^2 + 0.0000504(TL)^3$$

Deterministic pupping based on observed length compositions can only be calculated for the survey periods. For earlier years, an equilibrium population was simulated to provide a constant pupping rate at starting year (i.e., 1922) values for each region (i.e., 5.8 and 6.3 pups per mature female for the US and Canada, respectively). Annual pupping rates for each region's full time series comprise the constant pupping rate repeated over the earliest years, and the deterministic rates for the survey periods. A ramp of pupping rates is interpolated between the first years of the survey periods and the equilibrium constants intercepting at, or near, the first year of perceived high exploitation (Figure 2). The pattern for the US reflects exploitation patterns reasonably well, both before and during the observed period. The rapid drop for Canada reflects the lack of evidence for serious exploitation prior to 1966, which could simply reflect poor data.

Pupping rates are predicted by the model by treating the combined simulated and deterministic annual rates as if observed, and fitting the predictions to these values assuming a log SD of 0.4.

Poor representation of the size composition of adult females in the Canada Summer RV survey would likely distort the deterministic estimates of pupping rates for the Canadian component. Simulations indicated a high probability of extirpation of the Canadian component, even without fishing, using these pupping rates (and Canadian estimates of maturity at length). During the assessment review process, it was recommended that the deterministic pupping rates derived from the US Spring RV survey size composition be used for both regions.

Initial Population Size

Commercial catch data begins in 1922, while survey data begins in 1968 (US) or 1970 (Canada). Initial abundances of population components by region, sex and maturity stage are estimated by the model. Priors for initial (1922) abundances of US population components were estimated by simulating an equilibrium population. The resulting composition (relative proportions by sex and stage) is fixed, while the total abundance is estimated. Priors for initial abundances of Canadian components were determined as 10% of US components. These priors ensure that the population does not go extinct within the first iteration of model fitting, which would cause the modeling program to abort. Fitted initial abundances are much lower than the priors. An equilibrium population start in 1922 is not assumed; however, an equilibrium size composition is assumed, and it is expected that population estimates for the earliest years (perhaps the first three decades) represent a burn-in.

Recruitment

Pups recruit near the end of the first time step (March). For fitting purposes, it is assumed pupping is completed before the US Spring RV survey in March whereas, in reality, pupping is likely concurrent with this survey. An equal sex ratio at birth is assumed. The model structure assumes all female fish are in their home region at the time of pupping, and recruitment occurs in the home regions. The deterministic stock-recruitment relationship, based on calculated year-specific pups per mature female that are treated as observed values in the model, is shown in Figure 3.

Natural Mortality

There are separate natural mortality parameters for each sex and maturity stage (male and female; juvenile and adult). Natural mortality rates can be either fixed or estimated. When fixed, as in the models presented here, the natural mortality rates are assumed to be 0.1 for both sexes and stages.

The model allows for estimation of extra natural mortality on pups in their first six months.

Migration

There presently is not adequate data to indicate the numbers of dogfish that move between regions; therefore, movements of population components must rely on assumptions and/or model fitting estimates. Tagging studies thus far are limited by insufficient quantities released in the Canadian region and inappropriate release locations in the US region (Chesapeake Bay, which is too far south). The authors' perception of the migrations of dogfish is depicted schematically in Figure 4. Northerly spring/summer and southerly fall/winter movements are known, but the magnitudes in either direction are speculative. This complicates estimation of regional populations, as the timing of the most reliable surveys in each region coincide with the time periods that migrants from the other region would be resident. US dogfish may be further partitioned into two groups (Chesapeake Bay and Gulf of Maine components), both exhibiting north-south seasonal migrations. The Gulf of Maine dogfish may also conduct a gyre-like counter-clockwise movement, with Scotian Shelf dogfish believed to conduct seasonal spring/summer inshore and fall/winter offshore movements.

Migrations occur prior to fishing mortality determination in each time step (Canada to US time step 1, US to Canada time step 2). Exploitation is tracked separately by home region in both regions. All surviving migrants are assumed to return to their home region in the subsequent time step, with no leakage. Proportions migrating are estimated separately for each population component (sex and maturity stage). Migrations are estimated as mean proportions (bounded 0.0 to 0.5) by sex and stage with annual deviations of up to 1.9, producing effective bounds of 0.05 to 0.95. The estimated mean is treated as if observed with a large assumed error of log SD=0.6 to constrain the deviates. Migrants are explicitly accounted for when fitting to observed survey abundances (the predicted survey abundance for each sex/maturity stage is comprised of two separate components by home region).

Fishery and Survey Data

Fisheries and survey length frequency data were aggregated by region, year, time-step, fishery or survey, and sex. Length compositions are represented by 3 cm length bins ranging from 22-25 cm to 103-105 cm TL (the first and last bins being plus-groups for smaller and larger dogfish, respectively). Unsexed length frequency data was not used. Most cases of unsexed fishery length frequency data for fisheries derived from sampling that included sexed length frequencies. The two surveys used in the current model pose one gap in sexing for the US spring survey between 1973 and 1979. For these years, interpolated proportions at length between 1972 and 1980 were used (no attempt was made to reconcile these with unsexed proportions at length).

Exploratory analyses of the Canadian Summer RV survey data revealed that 1998 was characterized by extremely low bottom (gear depth) temperatures relative to any other year in the time series, and that this anomaly was present across individual strata (very low temperatures were present across the entire survey area). The observed 1998 abundance estimates for every component of the Canadian population are very low relative to adjacent 1997 and 1999 estimates, as are those for female components in the US survey (males also drop, but not by implausible magnitudes). The survey data includes several isolated instances of increases and decreases of unlikely magnitudes, but this is the only year exhibiting such redundancy across components in association with an known environmental anomaly. Therefore, the 1998 observations were replaced with the means of 1997 and 1999 for both surveys. Temperature data from the US survey could not be obtained for this assessment, but it is assumed the cold water event was common to both surveys.

Total absence of length frequency data for fisheries is the most common source of gaps in length composition. These gaps were filled in by manually looking at the length frequencies and typically using nearest-neighbour length frequencies (sometimes skipping small samples). This approach would be reasonable for brief gaps of a few years; however, there are large blocks of time in the early years for which no sampling was conducted. Thus, the length compositions of removals for most of the time series (1922-1982) are just those of the mid-1980s, which are not expected to be reasonable.

Length compositions for the Canadian Summer RV survey used stratified abundances as input. The length frequencies for the US Spring RV survey were relative numbers, possibly portions of the stratified mean. These were converted to stratified abundances at length by iteratively solving for the abundance at length that gave a total biomass corresponding to the stratified biomasses provided, using US male and female weight (W) at length relationships from an unpublished TRAC working paper:

$$W_{male}=0.0000023*TL^{3.1}$$

$$W_{female}=0.0000003*TL^{3.607}$$

Fishery length frequencies were converted to total removals at length by iteratively scaling them to total catch weights in the same manner as US survey length frequency conversions. The Canadian weight at length equations for this are:

$$W_{male}=0.0000085*TL^{2.81}$$

$$W_{female}=0.0000012*TL^{3.2695}$$

Maturity at length (discussed previously) was applied to fishery and survey abundances at length to produce abundances by sex and maturity stage.

Fishery discard catches at length were converted to numbers of dead fish by assuming discard mortalities for each fishery type, the assumed mortalities derived from a joint Canada/US TRAC meeting in 2010 (Haist et al. 2010) (Table 1).

Fishery components (landings and discards in numbers at length by domestic otter trawl, longline, gillnet, foreign otter trawl, recreational, scallop dredge, other) were aggregated by region, year, time step, sex and maturity stage. Tables 2 and 3 show the landings and discards by total weight for Canada and the US, respectively, before aggregating over fishery components and deriving sex-maturity stage components. Noting that within-year seasonal discards for the US Otter Trawl fishery were identical, while the within-year seasonal landings varied, discards were adjusted to reflect the proportions of the landings before aggregating. Tables 4 and 5 show the fishery removals, for Canada and the US, respectively, as input to the model (Figure 5 depicts these graphically).

Annual survey error estimates provide for flexibility in predicted abundances, but there are no formal statistical estimates of error for fishery removals. Given the paucity of commercial length composition data, especially during the early years, it is unlikely that the catch at length would be reasonable prior to the 1990s. The uncertainty in this data is accounted for by the creation of an assumed error by fishery (landings and discards treated as different fisheries for this exercise), year, and season, based on aspects of the length composition data. The premise is that the accuracy of the catch at length will be directly proportional to the quality of the length frequency sampling. The lowest SD allowed was .01 (on the log scale) and the highest SD allowed was 4.0. The highest SD was applied to 1922-1961, for which no sampling data exists. Any unsampled year from 1962 onward was attributed an SD of 1.0. For years with sampling, 250 fish was considered a good sample for a single trip and five trips was considered good sampling for a given fishery in one time step (six months). The Canadian length frequency data was not associated with trip counts, so a trip was proxied as just 250 fish, which is the typical maximum sample size for a port sampler. If more fish than this are available they are usually subsampled to equal 250 fish, such that 250 is both the most common and usually largest sample size observed. An SD for a fishery was then defined as:

> 1/ the minimum of (total number of fish sampled/1250, number trips/5) /100. **
>
> **applied through a number of nested min functions to bound the SD between 0.01 and 1.0; years prior to 1962 are just attributed 4.0

When aggregating the catch abundances over fishery components the SD for a region/year/season was computed as the catch-weighted mean of the component SDs. In application, most errors are 4.0 or 1.0 (no length composition data) and the lowest error encountered is 0.043. Table 6 gives an overview of the sampling and its associated error since 1922. The errors do not correlate directly with the total sampling numbers because the errors are catch-weighted by fishery, and major fisheries may be poorly sampled while minor fisheries are very well-sampled. The summary provides a general idea of the quality of the length composition data.

Table 7 summarizes the landings and discards for 1990-2013, depicting discard ratios and numbers-to-tons conversion factors for dogfish during years in which sampling may be considered adequate to represent them on an annual basis for US fisheries. Canadian fisheries were only sampled sufficiently for the purpose of computing numbers-to-tons conversions between 1998 and 2006.

Commercial catch data for years prior to 1979 preceded logging of month, so cannot be directly associated with the two time steps used in the model. The mean 1979-1985 proportions by time step for each fishery were prorated for these years.

Removals are modelled as component (sex and maturity stage) proportions of the total catch to facilitate re-allocation among the four catch components, as opposed to simply adjusting numbers of a component in isolation. In this way, the model can take advantage of the typically high catch errors by transferring removals between components without changing the total catch, and the composition is more likely to be further off than the total magnitude. This option is not used in the base model. So long as annual deviations on recruitment and maturation rates are implemented, catch re-allocation offers very slight improvements to model fitting at the statistical inference cost of huge numbers of parameters.

The total catch observations are vulnerable to time-invariant discard and reporting assumptions. These assumptions are often biased in favour of expectations for both long-term (regime) and short-term (seasonal) peak catch periods, which may be inappropriate (believed to be mostly excessive) during other periods. Thus, the model can allow for the predicted total catch to vary, but it is constrained to be within 75% to 105% of the observed catch. This option is not used in the base model.

The length frequency data used to construct maturity stage membership is all in TL fish measurements, while published size-based relationships are generally in FL measurements.

The following TL-to-FL conversions were used (Campana et al. 2009):

$$FL = -1.5 + 0.90\ TL$$

$$TL = 3.1 + 1.09\ FL$$

The 1922-1959 landings were not provided as electronic data. The US landings for this period were transcribed from a copy of a lab report from Woods Hole (Jensen et al. 1961). There is no information at all concerning Canadian landings before 1962. Landings throughout 1946-1961 were simply repeated as the low landings seen in 1962, and it was assumed there were essentially no landings for 1922-1945 (a tiny number to avoid division by zero). The report provides a detailed history of the US fishery prior to 1962, including landings back to 1915 (Table 8). The Jensen et al. (1961) report countered earlier assumptions (e.g. Canadian and US models reviewed during the 2010 TRAC process) that dogfish on the East Coast were relatively unexploited. A US government-subsidized World War II vitamin A fishery, which had a severe impact on West Coast dogfish, was not considered of concern on the East Coast due to the role of submarines acting as a deterrent to fishing. However, US fisheries on the East Coast were not inhibited by the war until 1942, and entered the vitamin A fishery when the war began. During the war they continued fishing, albeit to a lesser extent, in inshore areas that offered protection from submarines. Postwar, this fishery continued at a reduced rate until synthetic vitamin A became available in 1947, possibly reflecting loss of European fishing vessels during the war years. Canadian fisheries on the East Coast might have been able to catch dogfish inshore as well, but they did not participate in the vitamin A fishery as they were not provided subsidies as were US fisheries (difference in price of an order of magnitude). In 1948 the North American industrial (or trash) fishery started. Dogfish were briefly exploited by this fishery (major spike in catches in 1949) until it became apparent that they were harder to process than other species. There was subsequently little market for dogfish until 1956, by which time the reduction plants overcame the difficulties processing dogfish. North American trash fisheries then started to decline as the fishery for Peruvian ancovy expanded from 1960 to 1964 (Jensen 1967; Huntington et al. 2004). By the mid-to-late 1960s there was again no domestic market for dogfish. As 1959 is the end of the Jensen et al. (1961) landings table, and currently-available landings data start in 1962, the 1960-1961 catches were proxied to be the same as 1959.

In addition to the US Spring and Canadian Summer surveys used in current modelling to inform abundance estimation, several other surveys were considered and dropped during the modelling process. Most of these were dismissed during the TRAC modelling phase as unrepresentative of population-level dogfish abundance or of insufficient duration for a time series. The Canadian Individual Transferable Quotas (ITQ) and Georges Bank surveys only sampled portions of the area commonly inhabited by dogfish in Canadian waters, and the US Massachusetts Spring and Fall surveys predominantly caught males due to their inshore location, rather than the females characteristic of offshore US surveys. The Canadian March and Fall surveys were both short-lived surveys conducted in the 1980s, and the US Winter survey was conducted only between 1992 and 2007. The US Fall survey began in 1979 but gave results that were inconsistent with, and much more variable than, the US Spring survey. It was felt that the above surveys confused attempts to model population parameters, and their removal improved the model. The two remaining surveys, the US Spring (1968-present) and Canadian Summer (1970-present) were the longest time series, and are considered the best representatives of stock distribution in their respective jurisdictions. Figure 6 shows the total biomass estimates for the US Spring, Fall and Winter surveys. Figure 7 shows the total biomass estimates for the Canadian Summer survey.

Survey Catchability

Survey catchabilities are estimated separately by survey, sex, and maturity stage, and partitioned into periods of known or assumed differences in catchability (Table 9). The Canadian Summer survey is partitioned into two catchability periods representing two main vessels (A T Cameron and Alfred Needler) used to conduct the survey (no attempt was made to adjust for some single-year vessel substitutions). The US Spring survey is partitioned into four catchability periods. Two of these are different vessels, but two represent changes within the sampling period of the same vessel, which warrants some discussion.

An ad hoc investigation of US survey catchability was attempted via the Gulf of Maine website. This site provided some general applications for Northeast Fisheries Science Center (NEFSC) surveys. It only covered through 2003, so may not be maintained. However, it did provide a summary of sampling broken down by specific areas, which indicated gross changes in spatial coverage and sampling intensity between 1968-1987 and 1988-2003. Most importantly, a large change was seen in the intensity of sampling of the Continental Slope region of Georges Bank, which the distribution plotting apps on this site indicated was a primary source of dogfish catches. There is also information indicating that the survey was subject to an unintended gear alteration during 2000-2002, as the vessel underwent major overhauls in 1988 and 2003, and the vessel was changed in 2009. Any of these events could represent relevant sampling transitions, but the vessel change and gear alteration are the only formally documented transitions. The gear alteration was not deemed a concern; however, only the matter treated with respect to some major stocks assessed by VPA could be found, which may not be indicative of impacts on dogfish catchability.

To explore the possibility of non-vessel-specific changes in catchability in the US Spring survey, a series of simplified time-varying Q VPA models were run on unsexed US dogfish. All models used a common female growth model to represent length at age (trivial numbers of males reach lengths at which females mature), so would be inappropriate for population estimation, but offers insights into catchability issues on younger ages since sexual dimorphism is of little concern until about age ten. The reference year was adjusted to correspond to the last year of each potential catchability block: gross sampling change; accidental gear alteration; and vessel change, for the five periods inferred from the survey history. The overhauls were not considered sources of catchability change beyond the known accident. As a method to impose equal catchability regimes over non-contiguous years could not be determined, a separate Q estimate had to be generated for 2003-2008. Ideally 2003-2008 would be treated the same as 1988-1999 to give four non-contiguous Q regimes. This approach highlighted pronounced temporal patterns of absence and presence of pups in both survey and commercial catch numbers at age (Figure 8). There is also a lack of correspondence in these patterns between survey and commercial data sources, suggesting that the availability of pups may be subject to variations in location and timing of survey and fishery effort, perhaps relative to timing and location of pupping.

The commercial composition is extrapolated prior to the 1980s, but the lack of correlation in pup abundances between commercial and survey sampling is evident during 1980-2010. The temporal alternation between bimodal and unimodal selectivity this pattern imposes was a major stumbling block for the length-based TRAC model due to reliance on selectivity ogives, which the stage-based modelling approach was designed to circumvent. It would also suggest that the pups are not consistently monitored by the US Spring survey. Focusing on catchability of ages under ten, before sexual dimorphism would seriously confound catchability estimation from a unisex VPA model, suggests that the pup abundance patterns have limited potential to confound catchability estimates (Figure 9). However, large changes in catchability over time are purported by the VPA modelling (Table 10, Figure 9).This makes a supporting argument for the temporal variation in catchability inferred from survey histories, and also suggests that the stage-based approach should be reasonably robust to variation in pup catchability.

MODEL STRUCTURE

To represent migrations and capture population estimates proximate to surveys, the population dynamics were split into two periods, and further split the equations to accommodate exploitation of migrant dogfish when not in their home region. Canadian home region dogfish may move south in winter and US home region dogfish may move north in summer. All surviving dogfish are assumed to return to their home regions in winter (US) or summer (Canada). A detailed depiction of these equations is provided in Appendix 1, with the AD Model Builder (ADMB) code for the base model provided in Appendix 2. A descriptive summary of the approach is given here.

Equations in this section are indexed as:

r = region; 1 = Canada, 2 = USA

y = year; 1922-2010 (or 2013 for update models)

p = time step (period or season); 1 = November-April (winter), 2 = May-October (summer)

s = sex; 1 = male, 2 = female

m = maturity stage; 1 = juvenile, 2 = adult

The model starts with initial estimated abundances of population components (partitioned by region, sex, and maturity stage) and determines the transition of juveniles to adults for time period 1 (November-April),

$N_{ry[p=1]s[m=1]} = N_{r[y-1][p=2]s[m=1]} * (1.0 - \text{Theta}_{r[y-1]s})$;juveniles remaining juveniles

$N_{ry[p=1]s[m=2]} = N_{ry[p=1]s[m=2]} + (N_{r[y-1][p=2]s[m=1]} * \text{Theta}_{r[y-1]s})$; maturing juveniles added to adults

It then determines the Canadian home region exploitation rate from the Canadian home region catch,

$\text{ExploitationRate}_{[r=1]y[p=1]sm} = \text{Catch}_{[r=1]y[p=1]sm} / N_{[r=1]y[p=1]sm}$

where

$\text{Catch}_{rypsm} = (\text{CatchAdjustmentFactor}_{ryp}/(\Sigma\ \text{CatchProportion}_{ryp})) * \text{CatchProportion}_{rypsm} * \text{TotalCatch}_{ryp}$

Next the proportions of Canadian home region dogfish migrating to US waters are determined,

$\text{PropCANinUSA} = (N_{[r=1]y[p=1]sm} * (\text{CANUSAProportionMigrate}_{sm} * \text{CANUSAProportionMigrateDeviation}_{ysm}))/(N_{[r=2]y[p=1]sm} + (N_{[r=1]y[p=1]sm} * (\text{CANUSAProportionMigrate}_{sm} * \text{CANUSAProportionMigrateDeviation}_{ysm})))$

The US region exploitation rate on Canadian home region dogfish is then determined and added to the exploitation rate on Canadian dogfish,

$\text{ExploitationRate}_{[r=1]y[p=1]sm} = \text{ExploitationRate}_{[r=1]y[p=1]sm} + ((\text{Catch}_{[r=2]y[p=1]sm} * \text{PropCANinUSA}) / N_{[r=1]y[p=1]sm})$

The final survival rate of Canadian home region dogfish for period 1 is derived from the exploitation rate and natural mortality (exponential decay assumed).

$$\text{SurvivalRate}_{[r=1]y[p=1]sm} = (1.0 - \text{ExploitationRate}_{[r=1]y[p=1]sm}) * \exp(-\text{natmort}_{m} * 0.5)$$

$$N_{[r=1]y[p=1]sm} = N_{[r=1]y[p=1]sm} * \text{SurvivalRate}_{[r=1]y[p=1]sm}$$

US exploitation of US home region dogfish during period 1 must account for Canadian home region migrants, such that

$$\text{ExploitationRate}_{[r=2]y[p=1]sm} = (\text{Catch}_{[r=2]y[p=1]sm} * (1.0\text{-PropCANinUSA})) \,/\, N_{[r=2]y[p=1]sm}$$

and lastly the survival rate of US home region dogfish is calculated (preceding survival equation with r=2) before comparing catchability-adjusted predictions to observed survey abundances.

The above equations switch to accounting for migrations of US home region dogfish to Canadian waters for time period 2 (summer). The only other difference is invocation of recruitment. This would really overlap the time periods (winter-spring pupping), but it is sequenced to occur after the determination of maturity transitions, which would likely have been completed by the time pupping was accomplished. Pups derive from females that lived to the end of period 1, with a 50:50 sex ratio assumed. The model allows for estimation of additional immediate natural mortality on newborns (PupM), as opposed to assuming they experience the same mortality as juveniles in general.

$$\text{Recruits}_{ry} = N_{ry[p=2][s=2][m=2]} * \text{PupsPerMom}_{ry} * \exp(-\text{PupM})$$

$$N_{ry[p=2]s[m=1]} = N_{ry[p=2]s[m=1]} + (\text{Recruits}_{ry} * 0.5);\ \text{50:50 sex ratio}$$

LIKELIHOODS, PRIORS AND RESIDUALS

The catch and survey abundance data, and any parameter represented by an observed and estimated value, are fit assuming a lognormal distribution.

Lack of fit to survey abundance data is assumed to be comprised of four components: survey sampling error; variation in recruitment; variation in theta; and variation in migration.

In addition to the likelihood components for the catch and survey data, recruitment, theta and migration, the total objective function includes a prohibitive penalty function for survivorship reaching zero.

For diagnostic purposes, the model also includes the ability to estimate varying year-specific survey catchabilities with user-determined penalties.

All model residuals are output as Pearson residuals (i.e. standardized to a standard normal distribution).

Any of the likelihood components can be weighted, but this feature is only implemented in the current model for penalties on abundances going to zero.

The objective function is the sum of up to 38 standardized residuals, depending on which parameters are active for a given model, and 8 penalties. Contributors to this function comprise 8 survey fits (predicted versus observed by region, sex and maturity stage), 16 catch fits (predicted versus observed by region, season, sex and maturity stage), 2 pupping fits (predicted versus deterministic by region), 4 maturity rate fits (predicted versus deterministic by region and sex), 8 migration fits (deviations from predicted means by region, sex and maturity stage), and 8 survivorship penalties (each region, sex and maturity stage).

MODEL OUTPUTS

The model outputs a number of files that summarize aspects of the model run and/or cater to graphical presentation of the model fit. "R" code has been developed to graph model fits and residual distributions.

The primary output for assessing different components of a model's fit are statistics that summarize the residuals – the standard deviation of the standardized residuals (SDNR). These statistics have expected values of 1.0. This approach scales likelihood weights to be equal at the level of the degree of freedom (e.g. 10 years of survey abundance has the same influence as 10 years of catch abundance if fit with equal error), regardless of the magnitudes of data units (e.g. large abundance numbers vs fractional thetas).

MODEL RUNS

The length-based TRAC model (Figure 10) could not resolve the rate and magnitude of the increase in the population, evidenced by the surveys for all population components in the mid-1980s to mid-1990s. The stage-based model (Figure 11) with deterministic biological parameters for growth and recruitment is similarly challenged, but to a much lesser extent. The problem of reconciling survey estimates with biological parameters has also been noted in US assessments of dogfish, being attributed to a number of possible causes with inconsistency in distribution appearing a major factor that could be substantiated (NEFSC 2006), including variability of migration to Canadian waters (migration not modelled). Herding was also speculated but without substantiation.

The stage-based model follows the pattern of survey estimates fairly well and has little difficulty fitting to periods of low abundance, but falls shy of the survey peaks. Most of the Canadian survey abundances are predicted as migrants from US population components, not the local population, such that the annual deviates on migration give the summer predictions a more jagged appearance than spring predictions.

Partitioning survey catchability (Q) into four US spring and two Canadian summer temporal regimes improves the fit (Figure 12), but predictions are still notably less than survey observations for the US population components. Activating the annual deviates on maturity transition rates and pupping (Figure 13) allows the predictions for US females to rise up, possibly enough to address the problem. This model is referred to as the base model. Allowing for a plausible degree of herding (upper bound on catchability of 1.2) has almost no effect on fitting (very large Q's would be required to make a difference).

As a test of model rigour and evaluate for insights, a surplus production model developed for tuna (Meyer and Millar 1999) was adapted for dogfish. This model does not address partitioning of population components by region, sex or maturity. Without accounting for migration, this model cannot directly estimate population parameters. However, separate models of undifferentiated total abundances for US and Canadian regions might qualify as direct estimates of stock abundance in March (US) and July (Canada). By default, the surplus production model would also estimate the maximum intrinsic population growth rate (*r*), which it makes impossibly high. Attempts to constrain *r* to a reasonable value (at least 0.062 or less), using high precision on the prior, causes the model to abort. A constrained prior for *r* slightly higher than a plausible maximum (0.082 for Canada, 0.090 for US) was necessary to achieve a working model. Even with a high constant *r* the survey fits (Figure 14) indicate that this type of model has similar difficulty with the population peak as the stage-based model with deterministic biological parameters.

For a more direct comparison with the surplus production model, the stage-based model was conducted without migration in order to also estimate stock abundances rather than population abundances. Stage-based model fits for US components mirrored the migration model, but fits for Canadian components worsened without US migrants (Figure 15). Figure 16 shows estimates of total population abundances by region on the same scale for surplus production and stage-based models. Estimates of total stock abundance for the US are similar in both stage-based and surplus production models, but diverge considerably for Canada, with the surplus production model suggesting a much smaller Canadian stock. The magnitude of the Canadian population estimated by the surplus production model is very similar to that of the stage-based model estimate with migration.

Population components predicted by the stage-based model are depicted in Figure 17. The early years, up to about 1956, represent a burn-in to accommodate the trash fishery in a manner that will result in predicted population abundances compatible with survey observations beginning in 1968. To estimate a stable population for the earliest years would require some form of assumed or modelled density-dependence, and it is unclear if this would be valid given the highest predicted peaks correspond to those of the surveyed period. From the trash fishery onward the population goes up or down according to levels of exploitation. An estimate of the relative sizes of US and Canadian sub-populations might be taken from the 1956-1969 period, over which the Canadian population ranged from about 6-9% of the US population. However, the regional partitioning, necessary to model migration and fishery removals, should not be equated with the notion of biological sub-populations. The Canadian portion would approximate the number of dogfish that remain in Canadian waters throughout the winter, when most dogfish move farther south.

The model estimates appreciable migration of all US population components into Canadian waters (averaging 53-56%), while only males are estimated to migrate from Canadian to US waters (averaging 50-51%). The predicted migrations from US to Canadian waters are plausible, but Canadian females likely migrate as well. The smaller Canadian abundances of females relative to US abundances are probably insufficient to impact US survey fits such that the model poses no driver to move them. Heavy predicted exploitation of males in US waters lowers their abundances to be much closer to those of Canadian males such that migration of males from Canada can affect fits. Inter-annual variability in estimated proportions migrating from US to Canadian waters includes frequent occurrences of extreme values (Figure 18). Less flexibility in the allowable deviation might be warranted (perhaps a random walk approach).

Annual estimates of theta (Figure 19) vary erratically, conducting a mathematical balancing act to meet the abundance peaks in the 1985-1995 period. Smoother transitions for the US components would be expected rather than making such large changes up and down.

The model likley over-adjusts the pups per mature female (Figure 20) for the US component, trying to fit to extreme variations in survey observations. More gradual transitions at the high end, without the troughs, would be more likely. As a fitting strategy, it might not make a difference whether the adjustments use extremes or not, as they could balance out with the same overall magnitudes of difference as smoothed transitions. However, the approach would have implications for deriving reference points requiring estimates of maximum population growth rates (r).

Values of key model parameters and components of the likelihood function are summarized in Table 11.

MODEL DIAGNOSTICS

A standard statistical test for comparing Bayesian models, along the lines of comparing classical models with the Aikike Information Criterion (AIC), has not been developed yet. The ADMB website provides an article on Bayesian Inference that suggests rules for interpreting a Deviance Information Criterion (DIC) that was applied to the base model. Reduction of DIC by more than 10 is taken to argue in favour of the proposed parameters. If the reduction is less than 5, and the model inferences are unaffected, the parameters should be removed. These comparisons, summarized in Table 12, do not pose any serious issues of interpretation. The tests demonstrated that annual deviates on the Canada-to-US migration were unnecessary. Removing these had no discernible affect on model results.

REFERENCE POINTS

Deriving Maximum Sustainable Yield (MSY)-based estimates of key parameters carrying capacity (K), maximum intrinsic population growth rate (*r*), and a shape parameter to inform density-dependence (*s*), has been explored for Northeast Atlantic (Hammond and Ellis 2005) and Northeast Pacific (Gallucci et al. 2011) populations of dogfish. A recurring problem is a vast difference in empirically computed values (classical maximum likelihood) versus estimates obtained using Bayesian methods, typically of an order of magnitude. Direct contrasts using the same data are provided for both the Pacific population, for which an *r* of 0.42 calculated empirically compares with Bayesian estimates in the 0.016 to 0.084 range, and the Northeast Atlantic population, giving an empirical estimate of 0.42 versus Bayesian estimates in the 0.04 to 0.07 range. Both assessments dismissed the empirical method in favour of the Bayesian estimates.

Empirical estimates from stage-based model outputs (0.34 and 0.22 for US and Canadian components, respectively) correspond in magnitude to those of Hammond and Ellis (2005) and Gallucci et al. (2011). There have been no attempts to derive Bayesian estimates of reference point parameters from the stage-based model, as it does not include explicit estimation of density-dependence. At present, the range of Bayesian estimates for *r* suggested by the Northeast Atlantic and Pacific assessments are accepted as reasonable.

Carrying capacity is assumed to be at or above the observed peak in population abundance, applying simple iterative minimization starting at the observed peak and going up in 1% increments. Shape parameter estimation is constrained to require a biomass at MSY (B_{MSY}) within 50-80% of K. The shape parameter is also estimated by iterative minimization, but only works very close to 2.0 (+/- 0.1 exceeds the constraint). A recent exploration of the shape parameter for dogfish (De Oliveira et al. 2013), estimated it at 2.37 (5% 1.99, 95% 3.33 confidence intervals), although this was in relation specifically to pup production rather than population growth. A prompter response of pup production to density-dependent effects than population size might be expected, suggesting 2.0 could be a reasonable estimate.

Estimates of carrying capacity do not change greatly with different values of *r*, suggesting about 3.3 billion dogfish (4.4 million metric tons) for the US portion and 500 million (680,000 metric tons) for the Canadian portion of the population (Table 13). The US value is about twice the maximum predicted population peak, while the Canadian value corresponds with the maximum predicted population. Population estimates in recent years are 44% of the estimated B_{MSY} for the US and 0.4% of B_{MSY} for Canada. Estimates of MSY for a model with a single migrating population are similar to adding the above estimates of the two components (K = 3.9 billion dogfish or 5.3 million metric tons).

A concern with the estimation of dogfish carrying capacity is the role of the recent abundance peak in its determination. The rapid increase in the population, especially between 1983 and

1991, coincides with similarly rapid declines in the populations of other fish species that share the same habitat and trophic level as dogfish (e.g. western Scotian Shelf stocks of cod, haddock, and pollock). Decline of these competitors may have contributed to the unusually high rate of dogfish population growth during this period, suggesting it may not reflect normal growth. This raises the possibility of an observed population abundance that approaches or exceeds that of a population co-habiting a balanced ecosystem with competitors. Thus, the carrying capacity being estimated by the base model may overlap that of other species whose populations were reduced by 1991. If so, it would only be valid if other populations fail to recover. The post-1991 decline in dogfish abundance might also suggest the population had reached carrying capacity. However, 1992 is a common start year for an assumed low productivity regime across fish stock assessments, which could imply increased natural mortality is responsible for the decline, as opposed to a density-dependent response of dogfish. This would also mean a lower carrying capacity in current years than the model estimates.

For the purpose of deriving reference points in the context of MSY, the observed population peak is assumed likelier to represent the carrying capacity than the carrying capacity estimated by the model. Thus, it is assumed carrying capacity is 1441 (US portion) plus 42 (Canadian portion) yielding 1483 million fish (Table 14). This reduces MSY estimates considerably (over 50%), but also brings the recent population to 84% of B_{MSY}. Figure 21 depicts how this assumption translates into a perception of exploitation and stock status relative to MSY since 1956. The US plots essentially reflect the population (US portion represents 97% of the total carrying capacity), and indicate overfishing during 1958-61 (the industrial fishery) and 1969-77 (the foreign fishery). Although relatively few years are associated with overfishing, a majority of values fall under the estimated abundance at MSY (A_{MSY}), reflecting the protracted length of time it takes dogfish to recover from overfishing. The Canadian plots reflect the decline of the portion of the population estimated to overwinter in Canadian waters, which is not a suitable basis for MSY evaluations.

The $B/\ B_{MSY}$ ratio estimated by the model in 2009 is 1.06, as compared to 1.03 in the US assessment conducted in 2010 (Rago and Sosebee 2010). Although suggesting that the model resolves the US component compatibly with the US stock abundance model, the US uses a female SSB/SSB_{MSY} ratio, which could differ from a population ratio.

UPDATING WITHOUT US DATA

To update the dogfish assessment and monitor stock status indices with respect to Spiny Dogfish in Canadian waters, data may be limited to Canadian sources in the future, as dogfish is not being assessed through TRAC. The population model cannot accommodate this requirement. However, turning off migration in this model produces two separate series of stock abundance. This is equivalent to running two models that share the same objective function value. This provides a proxy for MSY that can be applied to Canadian fisheries during years when US data is unavailable. To evaluate the utility of this approach, it was used on both US and Canadian stocks with the base model data (Table 15), providing a direct comparison between population and stock abundance models using the same data. The carrying capacity (maximum predicted abundance) estimated for the US stock, 1550 million, is 5% higher than the 1483 million total population K of the base model, and 8% higher than the base model US sub-population estimate. The carrying capacity for the Canadian stock was inflated, as expected, to reflect local stock abundance at the time of the Summer RV survey. However without migration the Canadian stock abundance is depressed, at 303 million, by the model's inability to reconcile high survey observations with dogfish biology, as discussed earlier (Figure 15). This compares with a summer stock abundance of 626 million in the base (population) model. Combining the US and Canadian stock abundances inflates the total population estimate by 25%, primarily adding a Canadian stock abundance estimate to a population estimate. As well, the abundance estimated by the population model in the last year (2010) is 0.84 of B_{MSY}. This contrasts with stock abundance model values of 0.92 for Canada and 1.05 for the US, again reflecting the overestimation of abundance in stock versus population models.

The phase plots (Figure 22) for the US stock abundance model differ little from those of the population model, shifting slightly down and to the right, reflecting the 8% inflation of abundance. The phase plots for the Canadian stock are now decipherable in the context of historical fishing, with overexploitation evident during the foreign fishery (1972-1976). Canada did not participate in the earlier industrial fishery with respect to dogfish.

To gauge if the stock abundance models can provide precautionary reference points with their associated MSY assumptions, 100-year projections of abundance for a number of catch levels over a range of intrinsic population growth rates (r = 0.042, 0.052 and 0.062) were conducted. Candidate indices for monitoring stock status (exploitation (F) relative to F_{MSY}, % change in abundance) were applied to these projections to evaluate performance. For each projection, 11000 Markov Chain Monte Carlo (MCMC) iterations were generated, discarding the first 1000 and taking every 100th iteration for a projection sample.

All projections used constant deterministic (not estimated) maturation rates (theta) and the last observed pupping rate. These were derived from the length composition data, outside the model, prior to processing the numbers at length into the maturity stages for the model. The pupping rate would vary according to the length composition within the adult female stage, which would change from year to year, but it is being kept constant. This can be wrong in either direction (too low or too high) depending on if, and how, the projected catch composition would alter the length composition of adult females relative to the last observed year.

Projection catch composition for the US stock is generally assumed to be that of 2010. They have an ongoing and well-sampled fishery, as well as the suggestion of a declining trend in discard ratios, so this seems appropriate. For Canada, the mean of 1998-2006 is used given there is variability, but no trend is apparent, and these are years of reliable sampling of the Canadian catch composition.

For the US stock, the projection was based on the 2010 Total Allowable Landings (TAL) of 35.5 million pounds (or 16103 metric tonnes, mt). Determination of the US TAL includes an expectation of discards that appears to be the 2010 proportion of discards (23004 mt). It also includes consideration of Canadian catches by subtracting them from the TAL. But these derive from recent landings, do not include an adjustment for discards, and are predicted to be only 81 mt. So a second projection was done in which 2500 mt was added to the US catch. A third projection repeats the latter catch level but replaces the 2010 catch composition with a higher-adult composition from 2007. These catch levels are fairly close to what the US stock abundance model MSY would be with an r = 0.07 (35000 mt), which is thought to correspond to the estimated intrinsic population growth rate in the US assessment.

Canadian projections are conducted across a range of catch levels (500-4500 mt in 500 mt increments). The 2500 mt projection is also done with a higher adult catch composition from 2002. A third 2500 mt projection is done with the stock abundance model updated to 2013. The update (Figures 23 and 24), adding three years of Canadian data, demonstrates two years of continuing decline since 2010, then an increase in 2013 to approximately the same abundance as 2010. Most of the increase in abundance, however, is associated with males, while juvenile females are still declining.

Projection results for the US stock abundance model (Table 16) suggest that all scenarios are sustainable. Results for the Canadian stock abundance models (Table 17) suggest sustainability with the mean catch composition from the 2010 model, but not the updated 2013 model; the latter possibly reflecting the continued decline of juvenile female abundance. The higher adult composition with the 2010 model is also unsustainable.

The 100 year projections were used, but only the first 11 years and the 30th year are shown in Tables 16 and 17. Eleven years represents the lowest estimate of age at 50% maturity (A50) for a female dogfish, and 30 years the lowest estimate of generation time. For a long-lived species like dogfish, 11 and 30 years are short and medium-term projections.

It is evident across all projections that the earliest projection years do not provide information about sustainability with respect to a given catch level. The longevity of dogfish, coupled with its protracted juvenile pelagic stage, means there will be a long lag between impact and consequence. It is also clear that population F gives no warning within 30 projected years when there is overfishing. The problem is that there is a population-level F_{MSY} based on the historical catch composition, which requires stability in the catch composition at the overall model mean to work. In recent years, the catch composition has shifted towards more adults than the mean value. Another problem with F is adult females are such a small proportion of the total population (typically around 4%) that they make essentially no contribution to F. Thus, the adult females can be virtually wiped out before seeing any affect on F, so F_{MSY} may not be a suitable indice for monitoring. Abundance works provided projections are extended out enough to cover the lag.

Projection results suggest that it may be fine to utilize either population or US stock abundance models to define reference points and monitor status for five years before a new assessment, without updating, but not an updated Canadian stock abundance model. The most important information to monitor for these stocks is the catch composition. An increase in the proportion of females relative to that used to define reference points is of greatest concern.

Harvest Control Rule (HCR) plots are favoured for monitoring stock status and making management decisions. Preliminary HCRs for US and Canadian stock abundance models (Figures 25 and 26, respectively), and the updated Canadian stock abundance model (Figure 27), supported arguments that F_{MSY} might mis-represent stock status. These HCRs also used DFO defaults for reference points. It was noted during the internal review process that higher yields would probably be achieved by raising the Lower Reference Point (LRP) and Upper Stock Reference (USR) to safeguard the abundance of adult females, and reference points more suitable to dogfish should be investigated.

NEW INDICATORS

Given the poor performance of the F_{MSY} indicators and the long projection times required for the total abundance indicator to provide a meaningful signal, two new indicators were developed that work with adult females. Tracking adult female abundance (SSN) is one. The other is tracking F on adult females relative to a sustainable adult female F (F_{lim}). F_{lim} was determined by simulation independently of MSY assumptions like carrying capacity or assumed intrinsic population growth rates. Biological parameters were used to drive the population and it was fished at a range of catch levels to find the F at which the adult female abundance stabilizes. The corresponding B_{lim} estimated by this approach is equivalent to the proportion of B_{MSY} represented by a stable population composition. Adult females are about 4% of a stable population, and 4% of B_{MSY} corresponds to the simulated estimate of B_{lim}. Thus, although population MSY is confounded by changes in catch composition, the adult female proportion of B_{MSY} is not.

Projection results are summarized for the Canadian update (Tables 19-26) and US stock abundance (Tables 27-34) models, this time concentrating on sustainability signals giving results for probabilities of decline in total abundance or SSN over 10%, and of exceeding F_{MSY} at r =.042 (picking the fastest responder) or F_{lim}. The SSN and F_{lim} indicators are faster to respond to overfishing than the total abundance or F_{MSY} indicators. They can also provide an immediate signal in some cases (the US stock abundance model projections), although long-term projections indicate recovery at some catch levels that give an early warning signal.

RECOVERY POTENTIAL

A series of projections were applied to the stock abundance models to estimate how long it would take for the stock to recover to B_{MSY} if fished down to a given percent of B_{MSY} (Table 18). The results for the Canadian stock abundance model have little relevance, as in reality the stock is a function of migration, and US growth parameters would determine recovery times for both stocks. Thus, there is a focus on results for the US stock projections to gauge recovery potential.

Long recovery times, reaching up to 24 years at 40% of B_{MSY}, are largely due to early loss of adult females. Adult females are the first to go, and are knocked out well before the population as a whole reaches any appreciable percent of B_{MSY}. This exacerbates the lag problem discussed earlier with catch sustainability projections, as there may be no recruitment occurring for several years before reaching a given percent of B_{MSY}. Subsequently, juvenile females must then mature to create new recruits.

Dogfish would take eight years to recover if fished down to just 80% of B_{MSY}, a typical default USR for fish stocks. Given such long expectations for recovery, it is suggested that B_{MSY} itself, commonly used as a Removal (or Target) Reference Point (RR), represent the USR.

An estimate of the highest likely age of maturity (historical mean A50) for a female dogish is 14 years. This is how long it would take to recover to B_{MSY} if fished down to 65% of B_{MSY}. Thus, 65% of B_{MSY} is suggested as an LRP.

POPULATION MODEL UPDATE

As an alternative to relying on projections from 2010 models to cover the years between framework assessments, an approximate update of the model through 2013 was conducted. Canadian inputs were updated in the conventional manner. US inputs were obtained from summary information and by making some assumptions.

A 2013 US assessment (Rago and Sosebee unpublished document) and the current US Fisheries Management Plan (MAFMC 2014) for dogfish provide summaries of US landings through 2012 and US Spring RV survey biomass estimates through 2013. Assuming the 2010 catch composition and dead discard proportion remains appropriate, the catch data for 2011 and 2012 can be completed. For 2013, it is assumed the US TAL represents the total landings. The 2011-2013 survey data is derived from stratified biomass estimates partitioned by sex and size categories, which are assumed to reflect the maturity stages in the model. Differences in biomass between 2010 and subsequent years 2011-2013, within sex and stage, are treated as adjustment factors to increase or decrease abundances of 2010 components.

Fitting the updated model required re-activation of the deviation parameters on migration of Canadian components, which the DIC exercise on the 2010 model had turned off. The model completes without actually using them, but fitting them in earlier phases of the minimization assists with estimation of other parameters producing convergence. Without attempting to fit them a Hessian is not achieved.

There were no substantive changes to parameter estimates or temporal patterns in abundance estimates, and the fit remained reasonable (Figure 28). Overlaying the updated and 2010 model population estimates (Figure 29), the 2010 model ended in abundance troughs for all but adult females, which were increasing. The updated model demonstrates increase in abundance since 2009, especially of juveniles. Adult females, which had increased markedly in abundance in 2006, have remained at relatively high abundance since that time.

The update reinforced the adult female abundance, which translated into recruitment both deterministically in the 2010 projections and in the subsequent observed survey estimates for 2011-2013. The update preserved the original model trends in population components, and the 2011-2013 survey results, portraying increased abundance of the remaining components, are compatible with previous model predictions. However, the rate and magnitude of the increase is higher than previously predicted and this scales juvenile and adult male abundances up, relative to the 2010 model, raising the maximum population size and thus assumed carrying capacity. This increase in K also occurred in the 2013 US assessment model.

Harvest Control Rule charts for the two pairs of indicators (Figure 30 for Total Biomass with Fmsy; Figure 31 for SSN with F_{lim}) both reflect known periods of high exploitation during the industrial and foreign fishery years, but diverge during periods of lower exploitation. The SSN chart gives stronger signals during high exploitation, falling under the LRP, while the total biomass chart usually shows these years in the cautious zone. However, during periods of lower exploitation, such as in recent years, the total biomass chart contends Spiny Dogfish are in the cautious zone (below B_{MSY}) while the SSN chart contends they are over B_{lim}. This can be attributed to the difference between the historical catch compositions that inform MSY determinations and the catch compositions of recent years. This appears to confound B_{MSY} but not B_{lim}, as discussed below, when interpreting projection results.

POPULATION MODEL PROJECTIONS

Initially, projections were conducted applying the same assumptions that were used with the 2010 stock abundance model projections, except replacing the 2011 TAL with the current US TAL for 2014 as the projected US catch post-2013. The US TAL for 2014 is considerably higher than the 2011 TAL used in 2010 model projections, and alone is unsustainable according to the projections.

A major change to discard assumptions is evident in the current US assessment and Fisheries Management Plan relative to the assumptions on which the 2011 TAL was based. They now assume dead discards will equal the mean of 2002-2011 dead discards, rather than being proportional to landings (i.e. the landings increase, but the projected discards do not follow suit). This change was justified by the observed trend of decline in discards coupled with the assumption that discards will not be proportional to increased landings associated with directed fishing.

Projecting catch levels with current US discard assumptions, and focusing on just the total biomass, F_{MSY}, SSN and F_{lim} indicators, suggests catches of 47350 to 49100 mt could be removed from the population depending on catch composition assumptions and risk thresholds (Figure 32). Two regional catch ratio scenarios were projected: one using the mean ratio of fishery removals by region during 2002-2006 (a recent period of good sampling and directed fisheries in both regions) and a second scenario using the ratio of peak stock abundances by region. The latter scenario was termed the K ratio method, a nod to the assumption that peak estimated abundance reflects dogfish carrying capacity. However, the abundances for the ratio are the peak US Spring and Canadian Summer stock abundance estimates from the population model, not the population estimates of K.

Total biomass is projected to stabilize at a catch level higher than B_{MSY}, while SSN is projected to stabilize at an A_{lim} that equals 4% of A_{MSY} (B_{MSY} in numbers of fish), the proportion of adult females in a stable population simulation. It was intended to derive A_{lim} from the projection itself, but at present it is just represented as the product 0.04* A_{MSY}.These results suggest that B_{MSY} for the population is inappropriate, yet the adult female proportion of this B_{MSY} is appropriate. This reflects the difference between historical and recent catch compositions, distorting B_{MSY} at the population level in recent years. It is not assumed that A_{lim} would necessarily remain at 4% of A_{MSY}.

Table 35 summarizes the conversion of maximum sustainable catches from projections at P=0.5 into equivalent TACs. After adjusting for dead discards, Canadian TACs of 1894 mt (catch ratio method) or 5033 mt (K ratio method) are both estimated to be sustainable. Two further projections were conducted in which Canadian TAC candidates were simply added to the US 2015 TAL (Figure 33). Results suggest that neither TAC would be of concern provided the catch composition and discard assumptions of the projections are reflected in future fishing years.

SOURCES OF UNCERTAINTY

Sources of uncertainty are:

- Future catch and discard compositions are highly susceptible to deviation from the assumptions used in projections.
- Natural mortality (M) assumptions (especially since 1983).
- Historical discard assumptions.
- Discard mortality assumptions.
- Catch composition assumptions before the 1980s.
- RV Summer survey tracking of adult females.
- Carrying capacity may overlap that of reduced populations of other fish species.

CONCLUSIONS

A review of the modelling and reference point investigations conducted by the Canadian Science Advisory Secretariat (CSAS) on May 29, 2014 accepted the population model update approach as the method to monitor stock status during interim years. The SSN and F_{lim} stock status indicators, redefined as SSN_{MSY} and F_{SSN_MSY}, were adopted for the HCR, with 65% of SSN_{MSY} defining the LRP and SSN_{MSY} the USR (referred to as the Upper Reference Point in this document). The review chose the catch ratio method to determine F_{SSN_MSY}.

Annual tracking of catch and discard compositions is critical to monitor stock status.

The population model provides a reasonable basis for defining reference points and precautionary catch levels, but cannot be rigorously updated without US data. This could be achieved by assessing dogfish through TRAC.

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TABLES

Table 1. Discard mortality estimates determined during a 2010 dogfish TRAC meeting (Haist et al. 2010).

	Fishery						
Region	Longline	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Other Gear*	Scallop Dredge
Canada	0.1	0.25	0.55	0	0.25	0.1	NA
USA	0.1	0.5	0.3	0.25	0.5	0.5	0.75

*Other Gear = groundfish-directed longline for Canada.

Table 2. Canadian dogfish landings and discards in metric tons by fishery, year and time period (1=November-April, 2=May-October).

Year	Period	Landings							Discards							Total
		Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	
1922-1945	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1946-1962	1	8	1	0	0	0	0	0	0	1326	1433	0	0	824	0	3592
1963	1	8	1	0	0	0	0	0	0	1420	1535	0	0	882	0	3846
1964	1	8	1	0	0	0	0	0	0	1392	1505	0	0	866	0	3772
1965	1	8	1	0	0	76	0	0	0	1479	1598	0	0	919	0	4081
1966	1	33	5	1	0	3110	0	0	0	1594	1723	0	0	991	0	7458
1967	1	0	0	0	0	620	0	0	0	1526	1650	0	0	949	0	4744
1968	1	0	0	0	0	540	0	0	0	1609	1739	0	0	1000	0	4888
1969	1	0	0	0	0	363	0	0	0	1571	1698	0	0	977	0	4609
1970	1	0	1	0	0	143	0	0	0	165	437	0	0	307	0	1052
1970	2	16	1	0	0	553	0	0	0	1331	1180	0	0	623	0	3705
1971	1	0	0	0	0	197	0	0	0	162	429	0	0	301	0	1089
1971	2	3	0	0	0	758	0	0	0	1308	1160	0	0	612	0	3842
1972	1	0	0	0	0	1021	0	0	0	148	393	0	0	276	0	1839
1972	2	2	0	0	0	3935	0	0	0	1198	1063	0	0	561	0	6759
1973	1	0	1	0	0	1275	0	0	0	154	409	0	0	288	0	2127
1973	2	17	1	0	0	4910	0	0	0	1247	1106	0	0	584	0	7866
1974	1	1	2	0	0	1965	0	0	0	119	316	0	0	222	0	2625
1974	2	30	3	1	0	7572	0	0	0	964	855	0	0	451	0	9876
1975	1	0	0	0	0	1560	0	0	0	123	325	0	0	229	0	2237
1975	2	1	0	0	0	6009	0	0	0	992	880	0	0	464	0	8346
1976	1	0	0	0	0	1220	0	0	0	134	355	0	0	249	0	1958
1976	2	2	0	0	0	4700	0	0	0	1082	959	0	0	506	0	7250
1977	1	0	0	0	0	288	0	0	0	146	386	0	0	271	0	1091
1977	2	1	0	0	0	1111	0	0	0	1178	1044	0	0	551	0	3886
1978	1	1	5	0	0	8	0	0	0	172	455	0	0	320	0	961
1978	2	70	6	2	0	29	0	0	0	1388	1231	0	0	650	0	3376
1979	1	23	74	0	0	5	0	0	0	198	526	0	0	370	0	1195
1979	2	1109	99	27	0	30	0	0	0	1603	1422	0	0	750	0	5039
1980	1	11	37	0	0	74	0	0	0	210	557	0	0	391	0	1279
1980	2	550	49	13	0	293	0	0	0	1697	1505	0	0	794	0	4900

Year	Period	Landings							Discards							Total
		Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	
1981	1	10	32	0	0	67	0	0	0	220	583	0	0	410	0	1321
1981	2	470	42	11	0	491	0	0	0	1779	1578	0	0	833	0	5203
1982	1	7	22	0	0	25	0	0	0	231	614	0	0	431	0	1329
1982	2	324	29	8	0	27	0	0	0	1871	1659	0	0	876	0	4793
1983	1	0	0	0	0	151	0	0	0	217	576	0	0	405	0	1350
1983	2	0	0	0	0	233	0	0	0	1758	1559	0	0	822	0	4372
1984	1	0	0	0	0	6	0	0	0	209	553	0	0	389	0	1157
1984	2	2	0	0	0	307	0	0	0	1687	1496	0	0	790	0	4282
1985	1	0	1	0	0	33	0	0	0	215	571	0	0	401	0	1222
1985	2	11	1	0	0	379	0	0	0	1741	1544	0	0	815	0	4492
1986	1	0	0	0	0	21	0	0	0	698	341	0	0	180	0	1240
1986	2	8	2	0	0	216	0	0	0	1668	1862	0	0	913	0	4669
1987	1	3	1	0	0	1	0	0	0	811	347	0	0	458	0	1621
1987	2	223	25	5	0	93	0	0	0	1630	2083	0	0	934	0	4993
1988	1	13	0	0	0	275	0	0	0	590	134	0	0	403	0	1415
1988	2	0	0	0	0	272	0	0	0	1676	1741	0	0	1010	0	4699
1989	1	0	0	0	0	96	0	0	0	832	149	0	0	372	0	1449
1989	2	123	37	2	0	68	0	0	0	1279	2344	0	0	927	0	4780
1990	1	0	61	0	0	108	0	0	0	562	381	0	0	403	0	1515
1990	2	566	17	13	0	276	0	0	0	968	2510	0	0	1100	0	5450
1991	1	36	5	0	0	99	0	0	0	714	214	0	0	409	0	1477
1991	2	138	10	0	0	107	0	0	0	1676	1979	0	0	1121	0	5031
1992	1	0	0	0	0	45	0	0	0	738	151	0	0	428	0	1362
1992	2	515	38	2	0	0	0	0	0	1854	1475	0	0	1199	0	5083
1993	1	2	1	1	0	27	0	0	0	478	115	0	0	321	0	945
1993	2	590	24	112	0	0	0	0	0	1342	1137	0	0	820	0	4025
1994	1	1	0	5	0	0	0	0	0	311	27	0	0	105	0	449
1994	2	791	0	26	0	0	0	0	0	888	851	0	0	629	0	3185
1995	1	22	2	0	0	0	0	0	0	262	13	0	0	102	0	401
1995	2	328	3	42	0	0	0	0	0	741	854	0	0	372	0	2340
1996	1	1	1	0	0	0	0	0	0	323	2	0	0	67	0	394
1996	2	25	6	27	0	0	0	0	0	862	545	0	0	426	0	1891
1997	1	29	1	0	0	0	0	0	0	342	8	0	0	92	0	472

Year	Period	Landings							Discards							Total
		Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	
1997	2	125	8	107	0	7	0	0	0	1232	788	0	0	378	0	2645
1998	1	24	10	0	0	0	0	0	0	495	15	0	0	98	0	642
1998	2	732	13	92	0	0	0	0	0	1263	795	0	0	289	0	3184
1999	1	38	2	16	0	0	0	0	0	262	17	0	0	75	0	410
1999	2	1658	7	169	0	0	0	0	0	982	492	0	0	253	0	3561
2000	1	7	6	0	0	0	0	0	0	357	90	0	0	88	0	548
2000	2	2339	37	150	0	0	0	0	0	785	434	0	0	220	0	3965
2001	1	44	4	26	0	0	0	0	0	375	74	0	0	76	0	599
2001	2	2978	18	508	0	0	0	0	0	800	505	0	0	199	0	5008
2002	1	68	2	31	0	0	0	0	0	328	107	0	0	70	0	606
2002	2	2838	7	492	0	0	0	0	0	995	527	0	0	153	0	5012
2003	1	1	1	0	0	0	0	0	0	300	147	0	0	73	0	522
2003	2	868	5	418	0	0	0	0	0	887	515	0	0	134	0	2827
2004	1	0	1	0	0	0	0	0	0	344	120	0	0	62	0	527
2004	2	1945	1	343	0	0	0	0	0	698	668	0	0	99	0	3754
2005	1	86	1	0	0	0	0	0	0	346	71	0	0	35	0	539
2005	2	1926	4	294	0	0	0	0	0	779	449	0	0	93	0	3545
2006	1	31	1	0	0	0	0	0	0	226	59	0	0	44	0	361
2006	2	1896	1	513	0	0	0	0	0	597	276	0	0	104	0	3387
2007	1	26	1	0	0	0	0	0	0	271	9	0	0	46	0	353
2007	2	1926	8	426	0	0	0	0	0	703	313	0	0	121	0	3497
2008	1	23	0	0	0	0	0	0	0	242	16	0	0	47	0	328
2008	2	1395	2	126	0	0	0	0	0	695	295	0	0	110	0	2623
2009	1	12	0	0	0	0	0	0	0	276	3	0	0	55	0	346
2009	2	152	1	0	0	0	0	0	0	860	259	0	0	83	0	1355
2010	1	0	0	0	0	0	0	0	0	254	12	0	0	49	0	315
2010	2	5	0	0	0	0	0	0	0	842	265	0	0	91	0	1203
2011	1	0	4	0	0	0	0	0	0	201	4	0	0	47	0	256
2011	2	94	26	0	0	0	0	0	0	846	204	0	0	82	0	1252
2012	1	0	8	0	0	0	0	0	0	266	9	0	0	41	0	324
2012	2	0	57	0	0	0	0	0	0	954	153	0	0	70	0	1234
2013	1	5	0	0	0	0	0	0	0	171	2	0	0	32	0	210
2013	2	0	0	0	0	0	0	0	0	595	128	0	0	60	0	783

Table 3. US dogfish landings and discards in metric tons by fishery, year and time period (1=November-April, 2=May-October). Unavailable breakdowns for 2011-2013 are denoted with dashes (-) and the unavailable summary for 2013 is denoted by 'NA'.

Year	Period	Landings							Discards							Total
		Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	
1922	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1923	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	1	1	3	6	0	0	0	0	66	2305	17	0	0	0	0	2398
1925	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1926	1	0	1	2	0	0	0	0	20	709	5	0	0	0	0	738
1927	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1928	1	8	33	53	0	0	0	0	623	21662	160	0	0	0	0	22539
1929	1	9	40	65	0	0	0	0	760	26451	196	0	0	0	0	27521
1930	1	4	17	27	0	0	0	0	320	11118	82	0	0	0	0	11568
1931	1	2	8	13	0	0	0	0	148	5158	38	0	0	0	0	5367
1932	1	1	6	9	0	0	0	0	106	3695	27	0	0	0	0	3844
1933	1	1	3	5	0	0	0	0	61	2118	16	0	0	0	0	2203
1934	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	1	5	24	39	0	0	0	0	455	15834	117	0	0	0	0	16475
1936	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1937	1	3	14	23	0	0	0	0	270	9377	69	0	0	0	0	9756
1938	1	5	24	38	0	0	0	0	448	15582	115	0	0	0	0	16213
1939	1	5	21	35	0	0	0	0	403	14018	104	0	0	0	0	14585
1940	1	23	100	163	0	0	0	0	1893	65867	488	0	0	0	0	68533
1941	1	23	100	163	0	0	0	0	1893	65867	488	0	0	0	0	68533
1942	1	5	20	33	0	0	0	0	384	13367	99	0	0	0	0	13908
1943	1	5	22	35	0	0	0	0	413	14385	106	0	0	0	0	14967
1944	1	2	10	16	0	0	0	0	181	6290	47	0	0	0	0	6544
1945	1	2	10	16	0	0	0	0	187	6521	48	0	0	0	0	6784
1946	1	6	26	42	0	0	0	0	488	16989	126	0	0	0	0	17677
1947	1	2	7	12	0	0	0	0	136	4746	35	0	0	0	0	4938
1948	1	2	9	15	0	0	0	0	175	6101	45	0	0	0	0	6347
1949	1	25	108	176	0	0	0	0	2054	71474	529	0	0	0	0	74366
1950	1	5	24	38	0	0	0	0	448	15582	115	0	0	0	0	16213
1951	1	4	16	27	0	0	0	0	312	10847	80	0	0	0	0	11286
1952	1	2	9	14	0	0	0	0	163	5660	42	0	0	0	0	5889
1953	1	3	12	19	0	0	0	0	223	7770	58	0	0	0	0	8085

Year	Period	Landings							Discards							Total
		Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	
1954	1	2	10	16	0	0	0	0	190	6615	49	0	0	0	0	6883
1955	1	3	15	24	0	0	0	0	281	9765	72	0	0	0	0	10160
1956	1	20	87	141	0	0	0	0	1648	57330	424	0	0	0	0	59651
1957	1	49	214	348	0	0	0	0	4050	140910	1043	0	0	0	0	146614
1958	1	34	150	244	0	0	0	0	2846	99015	733	0	0	0	0	103023
1959	1	30	133	216	0	0	0	0	2517	87570	648	0	0	0	0	91115
1960	1	30	133	216	0	0	0	0	2517	87570	648	0	0	0	0	91115
1961	1	30	133	216	0	0	0	0	2517	87570	648	0	0	0	0	91115
1962	1	19	78	129	0	0	8	0	1554	51716	380	0	0	0	937	54822
1963	1	50	86	436	0	1	39	0	1554	51716	380	0	0	0	937	55198
1964	1	13	75	619	0	16	23	0	1554	51716	380	0	0	0	937	55333
1965	1	55	52	358	0	199	22	0	1554	50908	345	0	0	0	922	54415
1966	1	85	95	358	0	9389	40	0	1554	48730	531	0	0	0	883	61665
1967	1	24	111	98	0	2436	45	0	1554	44018	516	0	0	0	797	49599
1968	1	3	78	54	0	4404	23	0	1554	42748	713	0	0	0	774	50351
1969	1	2	88	6	0	9190	17	0	1554	39654	500	0	0	0	718	51730
1970	1	0	32	0	0	4003	4	0	173	18202	91	0	0	0	264	22769
1970	2	2	48	12	0	1637	7	0	3278	18202	365	0	0	0	396	23945
1971	1	0	21	0	0	9265	6	0	269	16512	98	0	0	0	239	26411
1971	2	0	32	4	0	2301	10	0	5119	16512	391	0	0	0	359	24727
1972	1	0	21	0	0	12357	6	0	266	14322	159	0	0	0	208	27337
1972	2	1	32	1	0	11634	9	0	5048	14322	636	0	0	0	311	31993
1973	1	0	31	0	0	12599	2	0	276	14246	166	0	0	0	206	27526
1973	2	0	46	4	0	6194	3	0	5241	14246	663	0	0	0	310	26707
1974	1	0	32	3	0	17094	14	0	274	13108	279	0	0	0	190	30993
1974	2	2	48	10	0	7419	21	0	5212	13108	1115	0	0	0	285	27219
1975	1	0	36	1	0	14384	17	0	264	11598	311	0	0	0	168	26779
1975	2	0	54	2	0	8139	26	0	5022	11598	1246	0	0	0	252	26339
1976	1	0	29	13	0	12025	14	0	168	12326	473	0	0	0	179	25225
1976	2	5	43	438	0	4763	21	0	3191	12326	1890	0	0	0	268	22945
1977	1	0	41	0	0	2247	11	0	117	14291	637	0	0	0	207	17551
1977	2	3	62	799	0	4952	16	0	2224	14291	2550	0	0	0	311	25207
1978	1	0	49	0	0	572	7	0	202	16914	860	0	0	0	245	18848
1978	2	3	73	675	0	50	10	0	3840	16914	3439	0	0	0	368	25371
1979	1	1	1407	12	0	187	7	0	267	17790	807	0	0	0	258	20736

Year	Period	Landings							Discards							Total
		Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	
1979	2	17	2111	1170	0	0	11	0	5065	17790	3230	0	0	0	387	29779
1980	1	1	1348	30	0	599	26	0	137	19311	1108	0	0	0	280	22840
1980	2	11	2022	638	0	0	39	0	2610	19311	4432	0	0	0	420	29483
1981	1	0	2515	0	597	936	3	0	93	18180	1072	118	0	0	263	23778
1981	2	1	3772	568	896	38	5	0	1768	18180	4288	178	0	0	395	30089
1982	1	0	2026	1	28	338	9	0	59	21455	891	140	0	0	311	25257
1982	2	3	3039	319	42	26	13	0	1126	21455	3563	209	0	0	466	30263
1983	1	0	1347	0	27	452	2	0	82	21094	808	216	0	0	306	24334
1983	2	0	2021	230	40	12	3	0	1567	21094	3234	324	0	0	459	28984
1984	1	0	994	1294	36	391	3	0	38	19813	984	170	0	0	287	24010
1984	2	1	1492	1955	55	0	5	0	727	19813	3934	254	0	0	431	28666
1985	1	8	1138	0	36	823	3	0	57	16677	908	386	0	0	242	20276
1985	2	151	1707	1017	53	189	5	0	1076	16677	3631	578	0	0	363	25447
1986	1	0	503	8	73	368	7	0	58	15873	977	475	0	0	230	18570
1986	2	2	755	1462	109	0	10	0	1095	15873	3906	712	0	0	345	24269
1987	1	0	739	0	122	129	13	0	111	14525	973	422	0	0	211	17247
1987	2	7	1109	678	134	10	20	0	2113	14525	3891	634	0	0	316	23486
1988	1	0	636	137	144	647	4	0	90	14476	1026	350	0	0	210	17719
1988	2	4	954	1495	215	0	5	0	1702	14476	4106	526	0	0	315	23797
1989	1	7	195	23	167	256	8	0	83	14143	1072	538	0	0	205	16697
1989	2	131	292	3789	251	0	12	0	1578	14143	4288	806	0	0	307	25598
1990	1	1	2804	174	72	393	1	0	57	17121	1212	468	0	0	248	22551
1990	2	16	4206	6696	107	0	2	0	1081	17121	4850	702	0	0	372	35154
1991	1	2	2083	3194	52	234	9	0	89	9661	2206	540	0	0	13	18084
1991	2	30	3125	3648	79	0	14	0	1700	9661	8824	810	0	0	19	27909
1992	1	0	1914	6413	86	67	101	0	30	16309	1191	408	0	0	331	26849
1992	2	9	2871	5392	129	0	151	0	576	16309	4762	611	0	0	496	31307
1993	1	13	2040	6505	48	27	9	0	0	8642	1963	444	0	0	84	19774
1993	2	238	3060	9313	72	0	14	0	0	8642	7851	666	0	0	125	29982
1994	1	41	1198	6453	62	2	55	0	160	6954	577	387	0	0	289	16179
1994	2	780	1797	9524	93	0	83	0	3041	6954	2310	581	0	0	434	25595
1995	1	84	952	5243	27	14	135	0	187	8499	1346	262	0	0	151	16901
1995	2	1603	1428	11480	41	0	203	0	3553	8499	5385	392	0	0	227	32811
1996	1	80	1341	8986	10	236	40	0	174	4701	778	132	0	0	48	16527
1996	2	1526	2011	10349	15	0	61	0	3314	4701	3112	197	0	0	73	25359

Year	Period	Landings							Discards							Total
		Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	Longline - Directed	Otter Trawl	Gillnet	Recreational Landings	Foreign Otter Trawl	Longline - Groundfish	Scallop Dredge	
1997	1	70	711	11535	26	214	40	0	235	3352	465	335	0	0	79	17062
1997	2	1322	1067	8000	40	0	60	0	4460	3352	1861	502	0	0	119	20783
1998	1	74	1043	7219	16	607	46	0	49	2634	393	244	0	0	48	12373
1998	2	1403	1565	10184	23	0	69	0	931	2634	1572	366	0	0	72	18819
1999	1	88	897	6938	21	554	106	0	267	3843	401	213	0	0	16	13344
1999	2	1665	1346	5297	32	0	159	0	5080	3843	1604	319	0	0	25	19369
2000	1	89	1270	2117	2	402	30	0	192	1364	937	274	0	0	6	6683
2000	2	1683	1905	1529	3	0	46	0	3650	1364	3747	411	0	0	8	14347
2001	1	66	96	199	11	677	10	0	119	2460	1441	840	0	0	12	5930
2001	2	1247	144	272	17	0	15	0	2269	2460	5763	1259	0	0	18	13463
2002	1	52	95	464	82	474	12	0	578	2770	999	669	0	0	23	6219
2002	2	996	142	557	123	0	18	0	10976	2770	3998	1004	0	0	35	20617
2003	1	32	15	291	16	643	31	0	16	1927	1083	1195	0	0	41	5290
2003	2	613	23	367	24	0	46	0	307	1927	4330	1792	0	0	62	9491
2004	1	1	60	379	42	330	20	0	130	4150	806	1396	0	0	21	7335
2004	2	24	90	344	63	0	30	0	2465	4150	3225	2094	0	0	32	12516
2005	1	3	100	137	18	330	59	0	29	3758	668	1404	0	0	6	6510
2005	2	53	150	585	27	0	89	0	546	3758	2670	2105	0	0	9	9992
2006	1	7	188	120	38	0	120	0	177	3887	674	1536	0	0	6	6751
2006	2	131	281	691	56	0	181	0	3357	3887	2695	2304	0	0	8	13592
2007	1	8	83	1524	34	0	269	0	104	4058	1027	1720	0	0	24	8850
2007	2	158	125	971	50	0	403	0	1972	4058	4106	2580	0	0	37	14460
2008	1	0.0	3	1068	24	0	175	0	31	2672	973	1246	0	0	95	6287
2008	2	265	271	1521	121	0	427	0	591	2672	3891	1869	0	0	142	11771
2009	1	0.0	1	1417	42	0	188	0	117	3727	2334	437	0	0	146	8409
2009	2	127	559	2293	20	0	598	0	499	1751	5324	1290	0	0	218	12679
2010	1	32.0	247	1403	8	0	143	0	613	4118	3374	485	0	0	143	10566
2010	2	572	349	2723	14	0	339	0	252	1651	2330	854	0	0	75	9159
2011	1 & 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22470
2012	1 & 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24327
2013	1 & 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NA

Table 4. Canadian fishery removals (numbers) by year, time step, sex and maturity.

Years	Time Step 1 (November-April)				Time Step 2 (May-October)			
	Males		Females		Males		Females	
	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults
1922-1945	100	100	100	100	100	100	100	100
1946-1962	5559	10388	137677	69305	17693	48294	160108	170947
1963	5948	11117	147274	74178	18932	51688	171253	182997
1964	5836	10906	144503	72771	18574	50708	168036	179520
1965	8279	13526	164960	80186	30118	60837	199191	197112
1966	92170	92581	648582	204862	447585	346266	1056823	474818
1967	23352	27764	251131	103277	105054	112430	351991	249272
1968	21502	26356	247351	104494	95200	108044	339820	253050
1969	16487	21517	216344	95675	70464	90331	286580	232967
1970	29744	32804	148878	74258	483103	206786	627632	230127
1971	38489	38856	170273	79741	578944	240981	731717	251372
1972	173394	134760	516179	177747	2114900	802594	2434258	659884
1973	215390	165361	628515	211764	2600281	982459	2979095	798547
1974	327487	243436	905877	286067	3857624	1438575	4361160	1122605
1975	261012	195885	733613	236168	3096135	1158390	3512777	910853
1976	205556	156846	593817	197625	2470425	930629	2822304	747979
1977	52833	48030	200691	85538	730698	293800	891795	282602
1978	7911	17745	95742	60989	239031	120548	364350	181409
1979	10073	23536	127289	91675	332677	200875	571927	479190
1980	20963	30867	152915	92381	444444	221717	654666	377898
1981	20066	30743	153862	93276	549794	259001	770549	392562
1982	13362	26383	139265	88831	329266	174209	518660	303256
1983	33023	38777	179983	92886	393563	182488	554926	232410
1984	12236	29911	116070	64042	418641	190239	578310	234591
1985	17095	34174	131491	69543	463004	208062	632084	252777
1986	21662	50001	95662	60756	375253	192902	551383	268976
1987	18350	15507	112490	87285	439527	183573	596308	332007
1988	68101	82744	146528	73056	562440	201084	971117	267988
1989	8382	18520	80875	86483	95200	248753	269309	361621
1990	18686	37943	126090	109694	804373	226529	1206234	490932
1991	27734	83274	156500	56736	137420	225892	364543	337396
1992	15385	63488	102526	44963	72896	268632	538932	298563
1993	5053	39090	63373	34252	56169	209802	428399	304219
1994	2121	19570	25634	15248	57804	156582	276458	314604
1995	4573	20037	41532	9856	61516	148102	360692	141643
1996	4338	20386	30009	8398	54350	160398	118121	74175
1997	5385	23838	50307	11967	94138	206050	347139	119113
1998	8352	35995	63780	16156	86479	413215	447138	154921
1999	5872	21393	54244	15010	23092	148140	766933	422938
2000	5523	26050	51124	20748	25313	158213	1000154	504533
2001	6598	28963	69507	30208	226039	725641	872244	589159
2002	6633	23545	81325	39325	43895	333055	728752	863416
2003	4850	27681	34178	26158	30654	222902	386040	331819
2004	5815	24082	40262	25316	64258	484230	581768	447760
2005	6904	42043	42544	32091	46029	402502	540211	495446
2006	3978	23630	26546	19213	58524	420550	531924	462671
2007	4235	23401	25221	12606	60971	435658	527027	461422
2008	3758	20635	23111	12411	46329	330232	371948	294634
2009	3884	20462	23489	9660	9744	88614	105051	84715
2010	3287	16832	20879	8221	7169	80145	76406	52062
2011	2803	14201	17500	6334	14193	96935	101055	60871
2012	3797	19158	23987	8748	11382	88256	91793	48060
2013	2192	11030	13659	4768	7886	50659	52872	30203

Table 5. US fishery removals (numbers) by year, time step, sex and maturity.

Year	Time Step 1 (November-April)				Time Step 2 (May-October)			
	Males		Females		Males		Females	
	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults
1922	148	1735	812	997	258	2031	960	443
1923	148	1735	812	997	258	2031	960	443
1924	14768	173524	81224	99684	25844	203060	95992	44304
1925	148	1735	812	997	258	2031	960	443
1926	4430	52057	24367	29905	7753	60918	28798	13291
1927	148	1735	812	997	258	2031	960	443
1928	138819	1631126	763506	937030	242934	1908764	902325	416458
1929	169832	1995526	934076	1146366	297206	2335190	1103908	509496
1930	70886	832915	389875	478483	124051	974688	460762	212659
1931	32490	381753	178693	219305	56857	446732	211182	97469
1932	23629	277638	129958	159494	41350	324896	153587	70886
1933	13291	156172	73102	89716	23260	182754	86393	39874
1934	148	1735	812	997	258	2031	960	443
1935	101899	1197316	560446	687820	178324	1401114	662345	305698
1936	148	1735	812	997	258	2031	960	443
1937	60549	711448	333018	408704	105960	832546	393567	181646
1938	98946	1162611	544201	667883	173155	1360502	643146	296837
1939	90085	1058496	495466	608072	157648	1238666	585551	270254
1940	420888	4945434	2314884	2840994	736554	5787210	2735772	1262664
1941	420888	4945434	2314884	2840994	736554	5787210	2735772	1262664
1942	85654	1006439	471099	578167	149895	1177748	556754	256963
1943	91562	1075849	503589	618041	160233	1258972	595150	274685
1944	39874	468515	219305	269147	69779	548262	259178	119621
1945	41350	485867	227427	279115	72363	568568	268778	124051
1946	109283	1284078	601058	737662	191246	1502644	710341	327850
1947	31013	364400	170570	209336	54272	426426	201583	93038
1948	38397	451162	211182	259178	67194	527956	249579	115190
1949	456331	5361892	2509822	3080236	798580	6274554	2966153	1368994
1950	98946	1162611	544201	667883	173155	1360502	643146	296837
1951	69410	815563	381753	468515	121467	954382	451162	208229
1952	36920	433810	203060	249210	64610	507650	239980	110760
1953	50211	589982	276162	338926	87870	690404	326373	150634
1954	42827	503220	235550	289084	74948	588874	278377	128482
1955	62026	728801	341141	418673	108545	852852	403166	186077
1956	366246	4303395	2014355	2472163	640931	5035888	2380602	1098739
1957	900848	10584964	4954664	6080724	1576484	12386660	5855512	2702544
1958	633547	7444180	3484510	4276444	1108708	8711274	4118057	1900642
1959	559707	6576560	3078390	3778024	979488	7695974	3638097	1679122
1960	559707	6576560	3078390	3778024	979488	7695974	3638097	1679122
1961	559707	6576560	3078390	3778024	979488	7695974	3638097	1679122
1962	344667	4251062	1991221	2457928	589811	4324514	2085464	938292
1963	344910	4261155	1997668	2520549	590096	4336759	2088054	960356
1964	345110	4256447	1998775	2544834	591165	4333330	2090643	969188
1965	344368	4203528	1990730	2481225	596851	4285966	2097667	946528
1966	558796	4526084	3158887	3367207	1322085	5002468	4042038	1305719
1967	354450	3760817	2034403	2370054	701351	3928997	2318320	909761
1968	395002	3758593	2256458	2507424	847636	4009556	2704879	967487
1969	493253	3760001	2776601	2850022	1202327	4212627	3630401	1109709
1970	688527	3003181	2567200	1535356	3084645	4123553	7064753	703607
1971	1222215	3556093	4324249	2215917	3185410	3934153	6931887	815750
1972	1520200	3736576	5291764	2564426	7188026	5439006	11084941	2218171
1973	1547811	3791875	5386382	2609592	4662887	4253830	8166829	1389426
1974	2008933	4310831	6915789	3219116	5087679	4299563	8457441	1592464
1975	1698924	3706090	5860173	2745480	5224921	4140869	8325806	1679214

Year	Time Step 1 (November-April)				Time Step 2 (May-October)			
	Males		Females		Males		Females	
	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults
1976	1459830	3456698	5081273	2448582	3762937	3602461	6753051	1267453
1977	445943	2225231	1728126	1108984	4115458	4098039	7538676	1437035
1978	308061	2342546	1318671	1018627	2191704	3616317	5885956	801132
1979	278752	2392810	1234530	1327644	2286512	3805202	6218568	1421610
1980	345255	2659999	1495020	1476220	2483365	4137527	6680498	1333954
1981	368843	2721762	1590458	1840430	2355330	3905108	6334614	1927872
1982	348271	2912167	1527625	1694083	2768010	4554669	7366943	1469630
1983	355279	2886788	1539096	1526185	2715197	4466162	7244266	1193144
1984	330621	2732556	1477111	1690262	2547229	4213781	6794698	1402368
1985	332344	2385571	1421347	1330751	2231046	3598056	5880749	1313220
1986	273069	2231922	1200357	1070636	2042526	3435240	5534320	1142342
1987	341890	1988028	1112180	1049976	2223839	3093657	5357692	1101666
1988	316558	2132745	1052605	1110495	2278398	3069708	5736061	1219838
1989	213028	2015110	964215	944493	1931169	3067497	5085401	1733963
1990	288201	2444796	1238776	1769919	3024694	3638445	7034608	3363504
1991	181341	1467322	877559	1908125	1199125	2341813	3647515	2535899
1992	279648	2420880	1256607	2849182	2434518	3637859	6569685	2747763
1993	655113	878411	1905683	2657204	1251457	2229390	4163664	3937968
1994	526426	739512	1780777	2616023	1246584	1690680	3593020	3830040
1995	1080195	1087873	3113936	2039026	2371294	4035167	4021616	4161222
1996	1039006	420161	2991339	3095043	3118941	1572333	6447003	3719899
1997	2109046	1172505	3465641	3354363	1151074	1994704	3000852	2699364
1998	4723010	1156860	6327793	2193035	899571	2606797	3021777	2967041
1999	4109748	937646	5850105	2339651	842686	1177431	2397006	2786352
2000	3111284	344054	3989237	1056337	304369	371241	2073530	1910330
2001	4909182	550960	5425964	326291	89605	284911	818218	1435839
2002	3475855	251153	3883798	586691	139842	404022	1035845	1433902
2003	4776397	388419	5220449	345636	294157	427755	996033	890739
2004	2522697	610251	3054029	510541	179593	570735	956757	1036588
2005	2406676	543779	2759840	439237	97614	666533	736798	982645
2006	128815	547593	354246	508958	299875	650424	924605	1198925
2007	181679	587238	562219	927442	193125	840424	733672	1399249
2008	510860	266135	692143	422129	556056	948983	1313758	1578851
2009	778522	197816	1002917	646953	950529	723987	1635170	2078460
2010	818802	472499	1173564	974759	358987	1005740	847506	1495059
2011	460483	578411	791806	977122	460483	578411	791806	977122
2012	534537	671431	919143	1134262	534537	671431	919143	1134262
2013	628788	789819	1081209	1334258	628788	789819	1081209	1334258

Table 6. Summary of length composition sampling and the assumed errors for removals derived from the sampling. Assumed errors are treated as logged standard deviations. 'NA' refers to 'not applicable'.

Year	Canada						US					
	Time step 1			Time step 2			Time step 1			Time step 2		
	Fish Measured	Trips Sampled	Assumed Error	Fish Measured	Trips Sampled	Assumed Error	Fish Measured	Trips Sampled	Assumed Error	Fish Measured	Trips Sampled	Assumed Error
1922-1961	0	0	4.00	0	0	4.00	0	0	4.00	0	0	4.00
1962-1979	0	0	1.00	0	0	1.00	0	0	1.00	0	0	1.00
1980	116	1	0.94	1	1	1.00	0	0	1.00	0	0	1.00
1981	0	0	1.00	0	0	1.00	6	6	1.00	0	0	1.00
1982	0	0	1.00	0	0	1.00	0	0	1.00	4	4	1.00
1983	0	0	1.00	0	0	1.00	108	9	0.89	480	5	0.88
1984	0	0	1.00	0	0	1.00	134	1	0.92	1514	19	0.81
1985	109	1	0.93	3510	14	0.79	2	2	1.00	1428	11	0.82
1986	1645	7	0.95	3093	13	0.88	264	16	0.94	1350	21	0.84
1987	861	3	1.00	7913	32	0.94	5	5	1.00	1912	19	0.86
1988	5319	22	0.50	1762	7	0.85	126	3	0.98	1828	72	0.82
1989	4163	17	0.78	3107	13	0.95	45	45	1.00	1637	34	0.40
1990	3586	14	0.71	2585	10	0.67	298	39	0.41	2328	34	0.13
1991	443	2	0.99	16	1	1.00	623	48	0.25	5259	69	0.09
1992	1762	7	0.87	531	3	0.98	1469	46	0.08	4341	141	0.53
1993	204	1	0.90	232	1	1.00	854	41	0.33	4188	60	0.31
1994	0	0	1.00	0	0	1.00	1100	64	0.10	5124	80	0.30
1995	213	1	1.00	983	5	1.00	14023	167	0.15	10027	144	0.14
1996	442	3	0.99	216	2	1.00	20045	188	0.05	6561	114	0.05
1997	217	1	1.00	2387	10	0.87	17365	236	0.04	6890	98	0.15
1998	122	1	1.00	3287	13	0.55	11508	163	0.28	17586	191	0.24
1999	10	1	1.00	1418	6	0.31	8211	146	0.10	8164	88	0.41
2000	617	2	1.00	1125	5	0.23	5206	74	0.40	4224	64	0.33
2001	211	2	0.81	3586	15	0.26	2015	59	0.45	2931	59	0.38
2002	141	1	0.75	12594	51	0.28	2003	88	0.31	7601	158	0.25
2003	0	0	1.00	90675	363	0.53	3389	101	0.44	17512	361	0.16
2004	0	0	1.00	146348	585	0.32	8173	215	0.27	32422	805	0.14
2005	0	0	1.00	290503	1162	0.29	23959	598	0.29	22117	689	0.15
2006	83	1	0.79	133156	534	0.31	14623	422	0.22	11586	298	0.17
2007	0	0	1.00	0	0	1.00	10968	261	0.18	16844	388	0.19
2008	0	0	1.00	0	0	1.00	6607	193	0.31	16239	523	0.17
2009	0	0	1.00	106	1	1.00	7060	241	0.19	17198	351	0.14
2010	0	0	1.00	2	1	1.00	6311	166	0.10	14374	217	0.10
2011	0	0	1.00	0	0	1.00	NA	NA	0.10	NA	NA	0.10
2012	0	0	1.00	1404	6	0.01	NA	NA	0.10	NA	NA	0.10
2013	0	0	1.00	61	1	0.21	NA	NA	0.10	NA	NA	0.10

Table 7. Discard ratios and fishery catch numbers-to-tons conversion factors for dogfish since initiation of representative sampling of length compositions by the US in 1990. Canada sampled adequately for this purpose between 1998 and 2006. 'NA' refers to 'not applicable'.

Year	**US**					**Canada**				
	Landed	Discarded	US Discard Ratio	US Dead Discard Ratio	US Number Dead Fish Per Ton	Canada Landed	Canada Discarded	Canada Discard Ratio	Canada Dead Discard Ratio	Canada Number Dead Fish Per Ton
1990	14472	43232	0.75	0.83	395	1041	5924	0.85	0.32	434
1991	12470	33523	0.73	0.74	308	395	6113	0.94	0.70	214
1992	17133	41023	0.71	0.79	382	600	5845	0.91	0.81	218
1993	21339	28417	0.57	0.66	355	757	4213	0.85	0.74	229
1994	20088	21687	0.52	0.57	384	823	2811	0.77	0.63	239
1995	21210	28501	0.57	0.59	441	397	2344	0.86	0.79	287
1996	24655	17230	0.41	0.44	535	60	2225	0.97	0.94	206
1997	23085	14760	0.39	0.32	501	277	2840	0.91	0.75	275
1998	22249	8943	0.29	0.18	766	871	2955	0.77	0.56	320
1999	17103	15611	0.48	0.24	625	1890	2081	0.52	0.26	367
2000	9076	11953	0.57	0.26	626	2539	1974	0.44	0.20	397
2001	2754	16641	0.86	0.22	714	3578	2029	0.36	0.14	454
2002	3014	23822	0.89	0.30	418	3438	2180	0.39	0.18	377
2003	2101	12680	0.86	0.25	902	1293	2056	0.61	0.36	318
2004	1383	18469	0.93	0.45	476	2290	1991	0.47	0.24	391
2005	1551	14953	0.91	0.38	523	2311	1773	0.43	0.20	394
2006	1813	18531	0.91	0.85	227	2442	1306	0.35	0.15	413
2007	3625	19686	0.84	0.73	233	2387	1463	0.38	0.16	403
2008	3875	14182	0.79	0.75	348	1546	1405	0.48	0.22	374
2009	5245	15843	0.75	0.74	380	165	1536	0.90	0.73	203
2010	5830	13895	0.70	0.68	362	5	1513	1.00	0.99	175
2011	10206	12264	0.55	NA	NA	124	1384	0.92	0.77	227
2012	12701	11626	0.48	NA	NA	65	1493	0.96	0.86	198
2013	NA	NA	NA	NA	NA	5	988	0.99	0.98	175

Table 8. Historic US East Coast landings in metric tons (mt) of dogfish derived from Jensen et al. (1961).

Year	Landings (mt)
1915	0
1919	29
1922	0
1923	0
1924	10
1925	0
1926	3
1927	0
1928	94
1929	115
1930	48
1931	22
1932	16
1933	9
1934	0
1935	69
1936	0
1937	41
1938	67
1939	61
1940	285
1941	285
1942	58
1943	62
1944	27
1945	28
1946	74
1947	21
1948	26
1949	309
1950	67
1951	47
1952	25
1953	34
1954	29
1955	42
1956	248
1957	610
1958	429
1959	379

Table 9. Summary of the US Spring RV survey with assumed catchability periods used in stage-based models. Number of sets by area (shown in table) and changes to survey design or vessel guided the assignment of regimes. Voids are denoted with dashes (-). There is no data for the number of sets after 2003.

Year	Bay of Fundy	Browns Bank	Central Gulf of Maine	Continental Slope	Eastern Coastal Shelf	Georges Bank	Georges Basin	Great South Channel	Jordan Basin	Northern Coastal Shelf	Scotian Shelf	Southern Coastal Shelf	Wilkinson Basin	Catchability Period	COMMENTS
1968	2	5	36	8	10	45	3	9	3	10	12	6	7	1	
1969	-	2	31	10	13	54	5	6	4	9	12	9	5	1	
1970	2	3	42	6	12	46	5	9	4	9	18	9	5	1	
1971	-	5	42	12	15	76	4	11	5	14	33	7	8	1	
1972	2	4	40	12	11	52	6	3	5	12	29	10	7	1	
1973	2	3	36	9	10	49	6	4	3	8	34	9	7	1	
1974	3	3	30	11	11	49	2	7	5	9	20	9	6	1	
1975	-	4	34	8	5	48	3	5	5	4	3	19	6	1	
1976	-	3	36	8	9	47	6	8	5	12	33	17	8	1	
1977	2	3	43	7	10	50	4	8	3	12	4	17	7	1	
1978	3	2	45	10	14	53	4	6	6	18	34	9	9	1	
1979	3	4	45	10	8	86	5	12	5	25	3	20	7	1	
1980	-	4	36	4	11	51	4	5	6	10	2	18	7	1	
1981	-	2	34	5	8	54	3	5	4	12	2	18	6	1	
1982	1	1	33	8	12	53	5	7	5	13	-	18	8	1	
1983	2	2	38	7	8	50	5	4	4	14	3	18	5	1	
1984	-	4	35	7	9	51	3	4	4	11	1	18	8	1	
1985	-	2	33	6	12	49	5	4	3	10	2	20	4	1	
1986	-	4	39	9	8	50	5	6	4	11	1	15	4	1	
1987	-	5	35	7	10	50	4	5	4	11	2	13	6	1	
1988	-	-	33	3	6	49	4	5	5	15	-	17	6	2	REFIT & SURVEY DESIGN CHANGES
1989	-	-	36	2	1	45	4	3	3	11	-	9	7	2	
1990	-	-	37	2	6	47	6	1	3	11	-	17	7	2	
1991	-	-	37	2	5	49	6	4	3	14	-	14	5	2	
1992	-	-	35	1		46	5	4	6	12	-	16	5	2	
1993	-	-	43	2	5	48	3	6	2	10	-	16	5	2	
1994	-	-	38	3	6	49	4	3	1	17	-	17	5	2	
1995	-	-	36	5	4	48	4	3	5	14	-	19	7	2	

Year	Bay of Fundy	Browns Bank	Central Gulf of Maine	Continental Slope	Eastern Coastal Shelf	Georges Bank	Georges Basin	Great South Channel	Jordan Basin	Northern Coastal Shelf	Scotian Shelf	Southern Coastal Shelf	Wilkinson Basin	Catchability Period	COMMENTS
1996	-	-	32	2	4	48	3	4	4	18	-	12	7	2	
1997	-	-	38	2	6	46	4	5	6	14	-	19	5	2	
1998	-	-	47	2	8	45	6	7	6	21	-	24	7	2	
1999	-	-	31	2		45	7	5	6	11	-	19	8	2	
2000	-	-	34	4	6	45	4	5	4	13	-	18	5	3	REFIT MISTAKE
2001	-	-	31	2	5	46	7	8	7	17	-	16	6	3	
2002	-	-	34	1	5	46	5	8	5	17	-	17	7	3	
2003	-	-	27	3	9	45	5	6	7	13	-	17	7	3	
2004	-	-	-	-	-	-	-	-	-	-	-	-	-	2	FIXED REFIT MISTAKE
2005	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
2006	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
2007	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	4	NEW SHIP
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	4	
2011	-	-	-	-	-	-	-	-	-	-	-	-	-	4	
2012	-	-	-	-	-	-	-	-	-	-	-	-	-	4	
2013	-	-	-	-	-	-	-	-	-	-	-	-	-	4	

Table 10. Mean catchabilities of young dogfish sampled by the US Spring RV survey, as estimated from time-varying-Q VPA modelling. Each column derives from a model in which the last year of the labelled period was the reference year.

Age	Q 1968-1987	Q 1988-1999	Q 2000-2002	Q 2003-2008	Q 2009-2013
0	0.01186	0.00633	0.00005	0.00010	0.00268
1	0.09816	0.08520	0.00004	0.00023	0.00669
2	0.03921	0.13965	0.00000	0.00006	0.00056
3	0.03962	0.09250	0.00000	0.00003	0.00002
4	0.06451	0.11104	0.00000	0.00016	0.00002
5	0.05588	0.12179	0.00001	0.00036	0.00004
6	0.06639	0.14858	0.00022	0.00321	0.00019
7	0.05922	0.14874	0.00258	0.03470	0.00061
8	0.05567	0.15175	0.02050	0.09155	0.00345
9	0.05759	0.25222	0.12691	0.15238	0.01413

Table 11. Summary table of stage-based model components. Fixed or estimated values derive from the final model. 'LF' refers to 'length frequency'.

Model Attributes	Aspect (Final Model)	Values or Priors; Phase; Range; Fit	Comments/Fits
		November-April (1) and May-October (2)	
		Canada and USA	
Annual growth and natural mortality fractions by time step	Model Design	.5,.5	-
Natural mortality (juvenile) parameter	Fixed	0.1; 6;0 .08-0.18; 0.1	-
Natural mortality (adult) parameter	Fixed	0.14; 6;0 .08-0.18; 0.14	-
Weight at length equation alpha (males) - Can	Fixed	0.0000085	Used to reconcile Fishery Removal Weights with Fishery LFs
Weight at length equation beta (males) - Can	Fixed	2.81	Used to reconcile Fishery Removal Weights with Fishery LFs
Weight at length equation alpha (females) - Can	Fixed	0.0000012	Used to reconcile Fishery Removal Weights with Fishery LFs
Weight at length equation beta (females) - Can	Fixed	3.2695	Used to reconcile Fishery Removal Weights with Fishery LFs
Weight at length equation alpha (males) - US	Fixed	0.0000023	Used to reconcile Survey Biomass and Fishery Removal Weights with Survey and Fishery LFs
Weight at length equation beta (males) - US	Fixed	3.1	Used to reconcile Survey Biomass and Fishery Removal Weights with Survey and Fishery LFs
Weight at length equation alpha (females) - US	Fixed	0.0000003	Used to reconcile Survey Biomass and Fishery Removal Weights with Survey and Fishery LFs
Weight at length equation beta (females) - US	Fixed	3.607	Used to reconcile Survey Biomass and Fishery Removal Weights with Survey and Fishery LFs
VB growth asymptote (Linf) parameter (male) - Can	Fixed	83.0	Used to produce growth matrices for determining juvenile-to-adult transition theta's
VB growth k parameter (male) - Can	Fixed	0.126	Used to produce growth matrices for determining juvenile-to-adult transition theta's
VB growth asymptote (Linf) parameter (female) - Can	Fixed	106.0	Used to produce growth matrices for determining juvenile-to-adult transition theta's
VB growth k parameter (female) - Can	Fixed	0.066	Used to produce growth matrices for determining juvenile-to-adult transition theta's
VB growth asymptote (Linf) parameter (male) - US	Fixed	82.5	Used to produce growth matrices for determining juvenile-to-adult transition theta's
VB growth k parameter (male) - US	Fixed	0.148	Used to produce growth matrices for determining juvenile-to-adult transition theta's
VB growth asymptote (Linf) parameter (female) - US	Fixed	100.5	Used to produce growth matrices for determining juvenile-to-adult transition theta's
VB growth k parameter (female) - US	Fixed	0.106	Used to produce growth matrices for determining juvenile-to-adult transition theta's
Pups per adult female of given length - Can	Fixed	Deterministic equation	Expected numbers of pups per adult female (US), treated as observed values
Pups per adult female of given length - US	Fixed	Deterministic equation	Expected numbers of pups per adult female (Can), treated as observed values
Pups per adult female - Can	Parameter Time Series	Deterministic equation; 5; 2.1-7.0;	-

Model Attributes	Aspect (Final Model)	Values or Priors; Phase; Range; Fit	Comments/Fits
		November-April (1) and May-October (2)	
		Canada and USA	
		prediction time series	
Pups per adult female - US	Parameter Time Series	Deterministic equation; 5; 2.1-7.0; prediction time series	-
Female proportion mature at length - Can	Fixed	Deterministic equation	Used to aggregate LF data by maturity stage
Female proportion mature at length - US	Fixed	Deterministic equation	Modification to Can equation
Male proportion mature at length - Can	Fixed	Deterministic equation	Used to aggregate LF data by maturity stage
Male proportion mature at length - US	Fixed	Deterministic equation	Modification to Can equation
Assumed Error (Log SD) on Pupping	Fixed	0.4	applies to both regions
Proportion male juveniles become adult, time step 1 - Can	Parameter Time Series	Deterministic equation; 4; 0.00-0.04; prediction time series	Theta
Proportion female juveniles become adult, time step 1 - Can	Parameter Time Series	Deterministic equation; 4; 0.00-0.04; prediction time series	Theta
Proportion male juveniles become adult, time step 2 - Can	Parameter Time Series	Deterministic equation; 4; 0.00-0.04; prediction time series	Theta
Proportion female juveniles become adult, time step 2 - Can	Parameter Time Series	Deterministic equation; 4; 0.00-0.04; prediction time series	Theta
Proportion male juveniles become adult, time step 1 - US	Parameter Time Series	Deterministic equation; 4; 0.00-0.04; prediction time series	Theta
Proportion female juveniles become adult, time step 1 - US	Parameter Time Series	Deterministic equation; 4; 0.00-0.04; prediction time series	Theta
Proportion male juveniles become adult, time step 2 - US	Parameter Time Series	Deterministic equation; 4; 0.00-0.04; prediction time series	Theta
Proportion female juveniles become adult, time step 2 - US	Parameter Time Series	Deterministic equation; 4; 0.00-0.04; prediction time series	Theta
Assumed Error (Log SD) on Theta	Fixed	0.6	applies to any transition
Extra natural mortality on pups	Parameter	0.0; 1; 0.0-0.5; 0.16	Applied to newborns upon recruitment
Can - Juvenile Male Abundance	Parameter Time Series	Can Summer Survey Estimates; 5; error; prediction time series	-
Can - Adult Male Abundance	Parameter Time Series	Can Summer Survey Estimates; 5; error; prediction time series	-
Can - Juvenile Female Abundance	Parameter Time Series	Can Summer Survey Estimates; 5; error; prediction time series	-
Can - Adult Female Abundance	Parameter Time Series	Can Summer Survey Estimates; 5; error; prediction time series	-
US - Juvenile Male Abundance	Parameter Time Series	US Spring Survey Estimates; 5; error; prediction time series	-
US - Adult Male Abundance	Parameter Time Series	US Spring Survey Estimates; 5; error; prediction time series	-
US - Juvenile Female Abundance	Parameter Time Series	US Spring Survey Estimates; 5; error; prediction time series	-
US - Adult Female Abundance	Parameter Time Series	US Spring Survey Estimates; 5; error; prediction time series	-
Can Summer Survey Error	Fixed Time Series	Can Summer Survey Estimates	same error across stages

Model Attributes	Aspect (Final Model)	Values or Priors; Phase; Range; Fit	Comments/Fits
		November-April (1) and May-October (2)	
		Canada and USA	
US Spring Survey Error	Fixed Time Series	US Spring Survey Estimates	same error across stages
Can - Juvenile Male Survey Catchability 1970-1981	Parameter	1.0 ; 1; 0.007-1.0; 0.012	logged in model; transformed values shown here
Can - Adult Male Survey Catchability 1970-1981	Parameter	1.0 ; 1; 0.007-1.0; 0.384	logged in model; transformed values shown here
Can - Juvenile Female Survey Catchability 1970-1981	Parameter	1.0 ; 1; 0.007-1.0; 0.009	logged in model; transformed values shown here
Can - Adult Female Survey Catchability 1970-1981	Parameter	1.0 ; 1; 0.007-1.0; 0.026	logged in model; transformed values shown here
Can - Juvenile Male Survey Catchability 1982-2010	Parameter	1.0 ; 1; 0.007-1.0; 0.071	logged in model; transformed values shown here
Can - Adult Male Survey Catchability 1982-2010	Parameter	1.0 ; 1; 0.007-1.0; 0.900	logged in model; transformed values shown here
Can - Juvenile Female Survey Catchability 1982-2010	Parameter	1.0 ; 1; 0.007-1.0; 0.081	logged in model; transformed values shown here
Can - Adult Female Survey Catchability 1982-2010	Parameter	1.0 ; 1; 0.007-1.0; 0.116	logged in model; transformed values shown here
US - Juvenile Male Survey Catchability 1968-1987	Parameter	1.0 ; 1; 0.007-1.0; 0.072	logged in model; transformed values shown here
US - Adult Male Survey Catchability 1968-1987	Parameter	1.0 ; 1; 0.007-1.0; 1.00	logged in model; transformed values shown here
US - Juvenile Female Survey Catchability 1968-1987	Parameter	1.0 ; 1; 0.007-1.0; 0.103	logged in model; transformed values shown here
US - Adult Female Survey Catchability 1968-1987	Parameter	1.0 ; 1; 0.007-1.0; 0.948	logged in model; transformed values shown here
US - Juvenile Male Survey Catchability 1988-1999 & 2003-2008	Parameter	1.0 ; 1; 0.007-1.0; 0.047	logged in model; transformed values shown here
US - Adult Male Survey Catchability 1988-1999 & 2003-2008	Parameter	1.0 ; 1; 0.007-1.0; 0.773	logged in model; transformed values shown here
US - Juvenile Female Survey Catchability 1988-1999 & 2003-2008	Parameter	1.0 ; 1; 0.007-1.0; 0.117	logged in model; transformed values shown here
US - Adult Female Survey Catchability 1988-1999 & 2003-2008	Parameter	1.0 ; 1; 0.007-1.0; 1.00	logged in model; transformed values shown here
US - Juvenile Male Survey Catchability 2000-2002	Parameter	1.0 ; 1; 0.007-1.0; 0.019	logged in model; transformed values shown here
US - Adult Male Survey Catchability 2000-2002	Parameter	1.0 ; 1; 0.007-1.0; 0.519	logged in model; transformed values shown here
US - Juvenile Female Survey Catchability 2000-2002	Parameter	1.0 ; 1; 0.007-1.0; 0.079	logged in model; transformed values shown here
US - Adult Female Survey Catchability 2000-2002	Parameter	1.0 ; 1; 0.007-1.0; 0.964	logged in model; transformed values shown here
US - Juvenile Male Survey Catchability 2009-2010	Parameter	1.0 ; 1; 0.007-1.0; 0.199	logged in model; transformed values shown here
US - Adult Male Survey Catchability 2009-2010	Parameter	1.0 ; 1; 0.007-1.0; 1.00	logged in model; transformed values shown here
US - Juvenile Female Survey Catchability 2009-2010	Parameter	1.0 ; 1; 0.007-1.0; 0.193	logged in model; transformed values shown here
US - Adult Female Survey Catchability 2009-2010	Parameter	1.0 ; 1; 0.007-1.0; 1.00	logged in model; transformed values shown here
Can - Juvenile Male Fishery Removal Proportions, Time Step 1	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
Can - Adult Male Fishery Removal Proportions, Time Step 1	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
Can - Juvenile Female Fishery Removal Proportions, Time Step 1	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
Can - Adult Female Fishery Removal Proportions, Time Step 1	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
US - Juvenile Male Fishery Removal Proportions, Time Step 1	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
US - Adult Male Fishery Removal Proportions, Time Step 1	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
US - Juvenile Female Fishery Removal Proportions, Time Step 1	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior

Model Attributes	Aspect (Final Model)	Values or Priors; Phase; Range; Fit	Comments/Fits
		November-April (1) and May-October (2)	
		Canada and USA	
US - Adult Female Fishery Removal Proportions, Time Step 1	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
Can - Juvenile Male Fishery Removal Proportions, Time Step 2	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
Can - Adult Male Fishery Removal Proportions, Time Step 2	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
Can - Juvenile Female Fishery Removal Proportions, Time Step 2	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
Can - Adult Female Fishery Removal Proportions, Time Step 2	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
US - Juvenile Male Fishery Removal Proportions, Time Step 2	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
US - Adult Male Fishery Removal Proportions, Time Step 2	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
US - Juvenile Female Fishery Removal Proportions, Time Step 2	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
US - Adult Female Fishery Removal Proportions, Time Step 2	Fixed Parameter Time Series	Observed; 5; 0.0-1.0; prediction time series	when estimating we use 0.85*Observed as prior
Can Catch Error, Time Step 1	Fixed Time Series	Derived from Can LF sampling data for Time Step 1	same error across stages
Can Catch Error, Time Step 2	Fixed Time Series	Derived from Can LF sampling data for Time Step 2	same error across stages
US Catch Error, Time Step 1	Fixed Time Series	Derived from US LF sampling data for Time Step 1	same error across stages
US Catch Error, Time Step 2	Fixed Time Series	Derived from US LF sampling data for Time Step 2	same error across stages
Can Total Catch Deviation, Time Step 1	Fixed Parameter Time Series	1.0 ; 5; 0.75-1.05; prediction time series	-
Can Total Catch Deviation, Time Step 2	Fixed Parameter Time Series	1.0 ; 5; 0.75-1.05; prediction time series	-
US Total Catch Deviation, Time Step 1	Fixed Parameter Time Series	1.0 ; 5; 0.75-1.05; prediction time series	-
US Total Catch Deviation, Time Step 2	Fixed Parameter Time Series	1.0 ; 5; 0.75-1.05; prediction time series	
Can->US Juvenile Male Proportion Migrate	Parameter	0.001; 2; 0.001-0.5; 0.5	-
Can->US Adult Male Proportion Migrate	Parameter	0.001; 2; 0.001-0.5; 0.5	-
Can->US Juvenile Female Proportion Migrate	Parameter	0.001; 2; 0.001-0.5; 0.5	-
Can->US Adult Female Proportion Migrate	Parameter	0.001; 2; 0.001-0.5; 0.5	-
US->Can Juvenile Male Proportion Migrate	Parameter	0.001; 2; 0.001-0.5; 0.5	-
US->Can Adult Male Proportion Migrate	Parameter	0.001; 2; 0.001-0.5; 0.5	-
US->Can Juvenile Female Proportion Migrate	Parameter	0.001; 2; 0.001-0.5; 0.001	-
US->Can Adult Female Proportion Migrate	Parameter	0.001; 2; 0.001-0.5; 0.001	-
Can->US Juvenile Male Proportion Migrate Deviation	Parameter Time Series	1.0; 3; 0.1-1.9; 1.0; prediction	-

Model Attributes	Aspect (Final Model)	Values or Priors; Phase; Range; Fit	Comments/Fits
		November-April (1) and May-October (2)	
		Canada and USA	
		time series	
Can->US Adult Male Proportion Migrate Deviation	Parameter Time Series	1.0; 3; 0.1-1.9; 1.0; prediction time series	-
Can->US Juvenile Female Proportion Migrate Deviation	Parameter Time Series	1.0; 3; 0.1-1.9; 1.0; prediction time series	-
Can->US Adult Female Proportion Migrate Deviation	Parameter Time Series	1.0; 3; 0.1-1.9; 1.0; prediction time series	-
US->Can Juvenile Male Proportion Migrate Deviation	Parameter Time Series	1.0; 3; 0.1-1.9; 1.0; prediction time series	-
US->Can Adult Male Proportion Migrate Deviation	Parameter Time Series	1.0; 3; 0.1-1.9; 1.0; prediction time series	-
US->Can Juvenile Female Proportion Migrate Deviation	Parameter Time Series	1.0; 3; 0.1-1.9; 1.0; prediction time series	-
US->Can Adult Female Proportion Migrate Deviation	Parameter Time Series	1.0; 3; 0.1-1.9; 1.0; prediction time series	-
Assumed Error (Log SD) on Deviations from mean Migration	Fixed	0.6	applies to any component
Initial (1922) US Total Abundance	Parameter	510000000; 5;0-1000000000;60564595	allocated to components based on simulated stable composition; acts as start of burn-in
Initial (1922) Can Total Abundance as proportion of US	Parameter	0.1; 5; 0.01-1.0; 0.1	allocated to components based on simulated stable composition; acts as start of burn-in
Can - Juvenile Male Survivorship Penalty	Penalty Time Series	all 0	posfun with eps = 0.0001 to keep abundance above 0.0
Can - Adult Male Survivorship Penalty	Penalty Time Series	all 0	posfun with eps = 0.0001 to keep abundance above 0.0
Can - Juvenile Female Survivorship Penalty	Penalty Time Series	all 0	posfun with eps = 0.0001 to keep abundance above 0.0
Can - Adult Female Survivorship Penalty	Penalty Time Series	invoked season 1 2005-2010 (sum to 0.07)	posfun with eps = 0.0001 to keep abundance above 0.0
US - Juvenile Male Survivorship Penalty	Penalty Time Series	all 0	posfun with eps = 0.0001 to keep abundance above 0.0
US - Adult Male Survivorship Penalty	Penalty Time Series	all 0	posfun with eps = 0.0001 to keep abundance above 0.0
US - Juvenile Female Survivorship Penalty	Penalty Time Series	all 0	posfun with eps = 0.0001 to keep abundance above 0.0
US - Adult Female Survivorship Penalty	Penalty Time Series	all 0	posfun with eps = 0.0001 to keep abundance above 0.0
Can - Juvenile Male Survey Catchability Deviation	Fixed Parameter	1.0 ; 5; 0.1-9.9; 1.0	for diagnostics
Can - Adult Male Survey Catchability Deviation	Fixed Parameter	1.0 ; 5; 0.1-9.9; 1.0	for diagnostics
Can - Juvenile Female Survey Catchability Deviation	Fixed Parameter	1.0 ; 5; 0.1-9.9; 1.0	for diagnostics
Can - Adult Female Survey Catchability Deviation	Fixed Parameter	1.0 ; 5; 0.1-9.9; 1.0	for diagnostics
US - Juvenile Male Survey Catchability Deviation	Fixed Parameter	1.0 ; 5; 0.1-9.9; 1.0	for diagnostics
US - Adult Male Survey Catchability Deviation	Fixed Parameter	1.0 ; 5; 0.1-9.9; 1.0	for diagnostics

Model Attributes	Aspect (Final Model)	Values or Priors; Phase; Range; Fit	Comments/Fits
		November-April (1) and May-October (2)	
		Canada and USA	
US - Juvenile Female Survey Catchability Deviation	Fixed Parameter	1.0 ; 5; 0.1-9.9; 1.0	for diagnostics
US - Adult Female Survey Catchability Deviation	Fixed Parameter	1.0 ; 5; 0.1-9.9; 1.0	for diagnostics
Can - Juvenile Male Survey Catchability Deviation Penalty	Penalty Time Series	0	Penalty_Weight *abs(log(Q/Q*deviation))
Can - Adult Male Survey Catchability Deviation Penalty	Penalty Time Series	0	Penalty_Weight *abs(log(Q/Q*deviation))
Can - Juvenile Female Survey Catchability Deviation Penalty	Penalty Time Series	0	Penalty_Weight *abs(log(Q/Q*deviation))
Can - Adult Female Survey Catchability Deviation Penalty	Penalty Time Series	0	Penalty_Weight *abs(log(Q/Q*deviation))
US - Juvenile Male Survey Catchability Deviation Penalty	Penalty Time Series	0	Penalty_Weight *abs(log(Q/Q*deviation))
US - Adult Male Survey Catchability Deviation Penalty	Penalty Time Series	0	Penalty_Weight *abs(log(Q/Q*deviation))
US - Juvenile Female Survey Catchability Deviation Penalty	Penalty Time Series	0	Penalty_Weight *abs(log(Q/Q*deviation))
US - Adult Female Survey Catchability Deviation Penalty	Penalty Time Series	0	Penalty_Weight *abs(log(Q/Q*deviation))
Can - Juvenile Male Survivorship Penalty Likelihood Component	Likelihood Weight	10	-
Can - Adult Male Survivorship Penalty Likelihood Component	Likelihood Weight	10	-
Can - Juvenile Female Survivorship Penalty Likelihood Component	Likelihood Weight	10	-
Can - Adult Female Survivorship Penalty Likelihood Component	Likelihood Weight	10	-
US - Juvenile Male Survivorship Penalty Likelihood Component	Likelihood Weight	10	-
US - Adult Male Survivorship Penalty Likelihood Component	Likelihood Weight	10	-
US - Juvenile Female Survivorship Penalty Likelihood Component	Likelihood Weight	10	-
US - Adult Female Survivorship Penalty Likelihood Component	Likelihood Weight	10	-

*Note: All likelihoods can be weighted. Only groups of components with members weighted off 1.0 are tabled.

Table 12. Model comparisons using the Deviance Information Criterion (DIC) to evaluate the contribution of parameters to model fits. A dash (-) indicates no value. 'NA' indicates 'not applicable'.

Phase	OFV	Estimated N of Parameters	DIC	Delta DIC	Added or Removed Parameters
0	184067	null model	-	-	0
1	13375	33	26488	NA	Add pup M, 8 migration means, 24 Q's
2	751	35	1541	24947	Add initial total population, proportion Canadian
3	649	379	1554	-13	Add migration deviates (8 * 89 years)
3	649	207	1436	105	Remove Canada to US migration deviates*
4	509	427	1347	89	Add theta deviates (4* 2 seasons * 89 years)
5	480	537	1254	93	Add pupping deviates (2 * 89 years)

*Same as adding US-to-Canada deviates.

Table 13. Base model estimates of K, Bmsy and MSY in millions of fish over a range of growth rates (r), partitioned by region during winter. The shape parameter (s) is held constant at 2.0. Population K is the sum of Canada + US Ks.

US							**Canada**						
r	**s**	**K**	**Bmsy**	**MSY**	**Fmsy**	**MSY in metric tons**	**r**	**s**	**K**	**Bmsy**	**MSY**	**Fmsy**	**MSY in metric tons**
0.017	2.0	3407	1703	14.5	0.0085	19567	0.017	2.0	503	252	2.1	0.0085	2891
0.022	2.0	3376	1688	18.6	0.0110	25091	0.022	2.0	503	252	2.8	0.0110	3741
0.027	2.0	3345	1672	22.6	0.0135	30512	0.027	2.0	503	252	3.4	0.0135	4591
0.032	2.0	3314	1657	26.5	0.0160	35827	0.032	2.0	503	252	4.0	0.0160	5441
0.037	2.0	3283	1642	30.4	0.0185	41038	0.037	2.0	503	252	4.7	0.0185	6292
0.042	2.0	3252	1626	34.1	0.0210	46144	0.042	2.0	503	252	5.3	0.0210	7142
0.047	2.0	3221	1611	37.8	0.0235	51145	0.047	2.0	503	252	5.9	0.0235	7992
0.052	2.0	3190	1595	41.5	0.0260	56042	0.052	2.0	503	252	6.5	0.0260	8842
0.057	2.0	3159	1580	45.0	0.0285	60835	0.057	2.0	503	252	7.2	0.0285	9692
0.062	2.0	3144	1572	48.7	0.0310	65847	0.062	2.0	503	252	7.8	0.0310	10543

Table 14. Maximum Sustainable Yield (MSY) over a range of growth rates (r) with carrying capacity (K) assumed as the maximum population abundance predicted by the base model.

Stock Definition	**Variable Description**	**Growth Rate Assumptions**		
Assumed Intrinsic Rate of Population Growth		*0.042*	*0.052*	*0.062*
Fmsy		*0.021*	*0.026*	*0.031*
US	Carrying Capacity (K in millions of fish)	1441	1441	1441
	MSY in millions of fish	15.1	18.7	22.3
	MSY in metric tons (approx)	20441	25308	30175
Canada	Carrying Capacity (K in millions of fish)	42.2	42.2	42.2
	MSY in millions of fish	0.4	0.6	0.7
	MSY in metric tons (approx)	599	742	884
Population	Carrying Capacity (K in millions of fish)	1483	1483	1483
	MSY in millions of fish	15.6	19.3	23.0
	MSY in metric tons (approx)	21040	26050	31059

Table 15. Maximum Sustainable Yield (MSY) over a range of growth rates (r) with carrying capacity (K) assumed as the maximum stock abundance predicted by the no-migration model.

Stock Definition	**Variable Description**	**Growth Rate Assumptions**		
Assumed Intrinsic Rate of Population Growth		*0.042*	*0.052*	*0.062*
Fmsy		*0.021*	*0.026*	*0.031*
US	Carrying Capacity (K in millions of fish)	1550	1550	1550
	MSY in millions of fish	16.3	20.2	24.0
	MSY in metric tons (approx)	21999	27237	32475
Canada	Carrying Capacity (K in millions of fish)	303	303	303
	MSY in millions of fish	3.2	3.9	4.7
	MSY in metric tons (approx)	4298	5321	6345

Table 16. US stock abundance model projection results for three catch level and catch composition scenarios.

Scenario	*USA catch=TAL* + 2010 proportion discards*					*USA catch=TAL* + 2010 proportion discards + 2500 mt (Canada)*					*USA catch=TAL* + 2010 proportion discards + 2500 mt (Canada)*				
Total Catch	*39107*					*41607*					*41607 - with 2007 catch composition*				
Probability of:	**Abundance Decline >10%**	**Abundance Increase >10%**	**F >Fmsy**			**Abundance Decline >10%**	**Abundance Increase >10%**	**F >Fmsy**			**Abundance Decline >10%**	**Abundance Increase >10%**	**F >Fmsy**		
Fmsy (r assumption)			*0.021*	*0.026*	*0.031*			*0.021*	*0.026*	*0.031*			*0.021*	*0.026*	*0.031*
Projection Year															
1	0	0.47	0	0	0	0.23	0.01	0	0	0	0	0.47	0	0	0
2	0	0.76	0	0	0	0.1	0.09	0	0	0	0	0.69	0	0	0
3	0	0.86	0	0	0	0.02	0.24	0	0	0	0	0.8	0	0	0
4	0	0.97	0	0	0	0	0.36	0	0	0	0	0.87	0	0	0
5	0	0.99	0	0	0	0	0.47	0	0	0	0	0.93	0	0	0
6	0	1	0	0	0	0	0.65	0	0	0	0	0.95	0	0	0
7	0	1	0	0	0	0	0.79	0	0	0	0	0.98	0	0	0
8	0	1	0	0	0	0	0.85	0	0	0	0	0.98	0	0	0
9	0	1	0	0	0	0	0.88	0	0	0	0	0.98	0	0	0
10	0	1	0	0	0	0	0.94	0	0	0	0	0.98	0	0	0
11	0	1	0	0	0	0	0.98	0	0	0	0	0.98	0	0	0
30	0	1	0	0	0	0	1	0	0	0	0.02	0.98	0	0	0

Table 17 a. Canadian stock abundance model and update model projection results for seven catch level and catch composition scenarios. Scenarios 1 and 2.

*Canadian catch=Landings + mean 1998-2006 proportion discards***										
Catch	*1500*					*2000*				
Probability of:	**Abundance Decline >10%**	**Abundance Increase >10%**	**F >Fmsy**			**Abundance Decline >10%**	**Abundance Increase >10%**	**F >Fmsy**		
Fmsy (r assumption)			*0.021*	*0.026*	*0.031*			*0.021*	*0.026*	*0.031*
Projection Year										
1	0	0.64	0	0	0	0	0.64	0	0	0
2	0	0.64	0	0	0	0	0.61	0	0	0
3	0	0.63	0	0	0	0	0.59	0	0	0
4	0	0.63	0	0	0	0	0.58	0	0	0
5	0	0.64	0	0	0	0	0.56	0	0	0
6	0	0.66	0	0	0	0	0.56	0	0	0
7	0	0.67	0	0	0	0	0.6	0	0	0
8	0	0.69	0	0	0	0	0.62	0	0	0
9	0	0.71	0	0	0	0	0.65	0	0	0
10	0	0.76	0	0	0	0	0.66	0	0	0
11	0	0.79	0	0	0	0	0.66	0	0	0
30	0	1	0	0	0	0	0.99	0	0	0

Table 17 b. Canadian stock abundance model and update model projection results for seven catch level and catch composition scenarios. Scenarios 3, 4 and 5.

Catch	*2500*					*2500 with 2002 catch composition*					*2500 using 2013 update model*				
Probability of:	Abundance Decline >10%	Abundance Increase >10%	F >Fmsy			Abundance Decline >10%	Abundance Increase >10%	F >Fmsy			Abundance Decline >10%	Abundance Increase >10%	F >Fmsy		
Fmsy (r assumption)			*0.021*	*0.026*	*0.031*			*0.021*	*0.026*	*0.031*			*0.021*	*0.026*	*0.031*
Projection Year															
1	0	0.64	0	0	0	0	0.64	0	0	0	0	0.53	0	0	0
2	0	0.61	0	0	0	0	0.6	0	0	0	0	0.48	0	0	0
3	0	0.56	0	0	0	0	0.51	0	0	0	0	0.45	0	0	0
4	0	0.54	0	0	0	0	0.48	0	0	0	0.03	0.39	0	0	0
5	0	0.5	0	0	0	0	0.48	0	0	0	0.04	0.38	0	0	0
6	0	0.5	0	0	0	0	0.48	0	0	0	0.08	0.37	0	0	0
7	0	0.51	0	0	0	0.01	0.47	0	0	0	0.13	0.37	0	0	0
8	0	0.52	0	0	0	0.01	0.47	0	0	0	0.17	0.35	0	0	0
9	0	0.52	0	0	0	0.05	0.46	0	0	0	0.2	0.34	0	0	0
10	0	0.53	0	0	0	0.14	0.44	0	0	0	0.24	0.33	0	0	0
11	0	0.53	0	0	0	0.16	0.41	0	0	0	0.25	0.33	0	0	0
30	0.01	0.7	0	0	0	0.57	0.24	0	0	0	0.54	0.24	0	0	0

Table 17 c. Canadian stock abundance model and update model projection results for seven catch level and catch composition scenarios. Scenarios 6 and 7.

Catch	*3000*					*3500*				
Probability of:	**Abundance Decline >10%**	**Abundance Increase >10%**	**F >Fmsy**			**Abundance Decline >10%**	**Abundance Increase >10%**	**F >Fmsy**		
Fmsy (r assumption)			*0.021*	*0.026*	*0.031*			*0.021*	*0.026*	*0.031*
Projection Year										
1	0	0.64	0	0	0	0	0.64	0	0	0
2	0	0.59	0	0	0	0	0.58	0	0	0
3	0	0.51	0	0	0	0	0.5	0	0	0
4	0	0.48	0	0	0	0	0.48	0	0	0
5	0	0.48	0	0	0	0	0.47	0	0	0
6	0	0.48	0	0	0	0	0.47	0	0	0
7	0	0.48	0	0	0	0.02	0.45	0	0	0
8	0.01	0.48	0	0	0	0.1	0.44	0	0	0
9	0.01	0.48	0	0	0	0.15	0.4	0	0	0
10	0.02	0.48	0	0	0	0.16	0.37	0	0	0
11	0.04	0.48	0	0	0	0.17	0.35	0	0	0
30	0.34	0.4	0	0	0	0.64	0.19	0	0	0

Table 18. Projected time for a population to recover to Bmsy if fished down to a given percent of Bmsy.

Fished Down to % of Bmsy	**Years to Recover to Bmsy**	
	US	**Canada**
40	24	58
50	18	49
60	15	42
70	13	35
80	8	15

Table 19. Canadian update model projection results for the probability of a decline in total abundance of 10% or more, for a range of catch levels, assuming the catch composition of 2013.

Projection Year	**Catch Levels**								
	500	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	0	0	0	0	0	0	0	0	0.01
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0.02
33	0	0	0	0	0	0	0	0	0.1
34	0	0	0	0	0	0	0	0.02	0.19
35	0	0	0	0	0	0	0	0.06	0.22
36	0	0	0	0	0	0	0.02	0.16	0.24
37	0	0	0	0	0	0	0.05	0.22	0.29
38	0	0	0	0	0	0	0.11	0.23	0.32
39	0	0	0	0	0	0.02	0.19	0.25	0.35
40	0	0	0	0	0	0.04	0.22	0.29	0.38
41	0	0	0	0	0	0.09	0.23	0.32	0.41
42	0	0	0	0	0.01	0.16	0.24	0.35	0.45
43	0	0	0	0	0.02	0.2	0.28	0.37	0.5
44	0	0	0	0	0.05	0.22	0.31	0.41	0.56
45	0	0	0	0	0.07	0.23	0.34	0.41	0.6
46	0	0	0	0	0.14	0.23	0.35	0.46	0.63
47	0	0	0	0.02	0.19	0.25	0.37	0.48	0.68
48	0	0	0	0.02	0.21	0.29	0.38	0.55	0.73
49	0	0	0	0.04	0.22	0.31	0.41	0.6	0.74
50	0	0	0	0.05	0.22	0.33	0.41	0.61	0.75
60	0	0	0.11	0.23	0.34	0.46	0.66	0.82	0.94
70	0	0.03	0.22	0.32	0.41	0.61	0.77	0.93	0.98
80	0	0.11	0.23	0.35	0.47	0.68	0.87	0.95	0.98
90	0	0.16	0.25	0.37	0.53	0.73	0.9	0.96	0.98
100	0.02	0.19	0.28	0.39	0.57	0.74	0.91	0.97	0.98

Table 20. Canadian update model projection results for the probability of a decline in adult female abundance of 10% or more, for a range of catch levels, assuming the catch composition of 2013.

Projection Year	**Catch Levels**								
	500	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0.02
29	0	0	0	0	0	0	0	0	0.07
30	0	0	0	0	0	0	0	0.02	0.2
31	0	0	0	0	0	0	0	0.08	0.23
32	0	0	0	0	0	0	0.02	0.19	0.24
33	0	0	0	0	0	0	0.05	0.22	0.31
34	0	0	0	0	0	0.01	0.14	0.23	0.34
35	0	0	0	0	0	0.02	0.2	0.28	0.37
36	0	0	0	0	0	0.05	0.22	0.32	0.41
37	0	0	0	0	0	0.11	0.23	0.34	0.43
38	0	0	0	0	0.02	0.19	0.25	0.36	0.47
39	0	0	0	0	0.03	0.22	0.29	0.39	0.55
40	0	0	0	0	0.05	0.22	0.32	0.41	0.6
41	0	0	0	0	0.11	0.23	0.34	0.45	0.62
42	0	0	0	0.01	0.16	0.24	0.35	0.47	0.66
43	0	0	0	0.02	0.2	0.28	0.37	0.52	0.73
44	0	0	0	0.03	0.22	0.29	0.39	0.56	0.74
45	0	0	0	0.05	0.22	0.32	0.41	0.6	0.74
46	0	0	0	0.06	0.23	0.34	0.43	0.61	0.77
47	0	0	0	0.11	0.23	0.35	0.46	0.66	0.8
48	0	0	0.01	0.16	0.24	0.36	0.48	0.68	0.86
49	0	0	0.02	0.19	0.27	0.37	0.52	0.73	0.88
50	0	0	0.02	0.21	0.29	0.39	0.56	0.74	0.9
60	0	0.02	0.19	0.28	0.38	0.55	0.73	0.9	0.96
70	0	0.05	0.23	0.34	0.45	0.64	0.8	0.94	0.98
80	0	0.14	0.24	0.36	0.49	0.73	0.88	0.96	0.98
90	0.01	0.19	0.28	0.37	0.56	0.74	0.91	0.96	0.98
100	0.02	0.19	0.29	0.39	0.58	0.74	0.92	0.97	0.98

Table 21. Canadian update model projection results for the probability of exceeding F_{MSY} at an assumed r of 0.042, for a range of catch levels, assuming the catch composition of 2013.

Projection Year	Catch Levels								
	500	1000	1500	2000	2500	3000	3500	4000	4500
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0.04
39	0	0	0	0	0	0	0	0	0.12
40	0	0	0	0	0	0	0	0.02	0.21
41	0	0	0	0	0	0	0	0.05	0.22
42	0	0	0	0	0	0	0	0.13	0.25
43	0	0	0	0	0	0	0.02	0.21	0.29
44	0	0	0	0	0	0	0.05	0.22	0.34
45	0	0	0	0	0	0	0.11	0.23	0.36
46	0	0	0	0	0	0.01	0.19	0.28	0.39
47	0	0	0	0	0	0.02	0.22	0.32	0.41
48	0	0	0	0	0	0.05	0.23	0.34	0.46
49	0	0	0	0	0	0.11	0.24	0.36	0.51
50	0	0	0	0	0	0.18	0.28	0.39	0.58
60	0	0	0	0.08	0.23	0.35	0.48	0.73	0.89
70	0	0	0.11	0.23	0.35	0.49	0.73	0.89	0.96
80	0	0.03	0.22	0.32	0.41	0.61	0.78	0.94	0.98
90	0	0.1	0.23	0.35	0.48	0.73	0.87	0.96	0.98
100	0	0.16	0.25	0.37	0.55	0.74	0.91	0.96	0.98

Table 22. Canadian update model projection results for the probability of exceeding F_{lim}, for a range of catch levels, assuming the catch composition of 2013.

Projection Year	**Catch Levels**								
	500	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0.02
29	0	0	0	0	0	0	0	0	0.05
30	0	0	0	0	0	0	0	0.01	0.2
31	0	0	0	0	0	0	0	0.03	0.22
32	0	0	0	0	0	0	0	0.11	0.24
33	0	0	0	0	0	0	0.02	0.2	0.29
34	0	0	0	0	0	0	0.04	0.22	0.34
35	0	0	0	0	0	0	0.11	0.24	0.37
36	0	0	0	0	0	0.01	0.19	0.29	0.4
37	0	0	0	0	0	0.02	0.22	0.32	0.41
38	0	0	0	0	0	0.05	0.23	0.34	0.47
39	0	0	0	0	0	0.12	0.24	0.37	0.53
40	0	0	0	0	0.01	0.19	0.29	0.39	0.6
41	0	0	0	0	0.02	0.22	0.32	0.41	0.61
42	0	0	0	0	0.05	0.22	0.34	0.45	0.66
43	0	0	0	0	0.06	0.23	0.35	0.48	0.73
44	0	0	0	0	0.14	0.24	0.37	0.55	0.74
45	0	0	0	0.01	0.19	0.28	0.39	0.58	0.74
46	0	0	0	0.02	0.21	0.3	0.41	0.6	0.77
47	0	0	0	0.03	0.22	0.32	0.41	0.62	0.8
48	0	0	0	0.05	0.22	0.34	0.45	0.66	0.85
49	0	0	0	0.06	0.23	0.35	0.47	0.69	0.87
50	0	0	0	0.11	0.24	0.36	0.5	0.73	0.9
60	0	0	0.11	0.24	0.36	0.5	0.73	0.9	0.96
70	0	0.03	0.22	0.32	0.41	0.62	0.8	0.94	0.98
80	0	0.11	0.23	0.35	0.48	0.73	0.88	0.96	0.98
90	0	0.16	0.25	0.37	0.55	0.74	0.91	0.96	0.98
100	0.01	0.19	0.28	0.39	0.58	0.74	0.92	0.97	0.98

Table 23. Canadian update model projection results for the probability of a decline in total abundance of 10% or more, for a range of catch levels, assuming the catch composition of 2002 (higher proportion of adult females).

Projection Year	**Catch Levels**					
	0	**500**	**1000**	**1500**	**2000**	**2500**
1	0.01	0.01	0.01	0.01	0.01	0.01
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0.02
38	0	0	0	0	0	0.04
39	0	0	0	0	0	0.11
40	0	0	0	0	0	0.18
41	0	0	0	0	0.02	0.21
42	0	0	0	0	0.02	0.22
43	0	0	0	0	0.05	0.23
44	0	0	0	0	0.11	0.25
45	0	0	0	0	0.16	0.29
46	0	0	0	0	0.2	0.32
47	0	0	0	0.02	0.22	0.34
48	0	0	0	0.02	0.22	0.35
49	0	0	0	0.04	0.23	0.37
50	0	0	0	0.05	0.24	0.38
60	0	0	0.04	0.23	0.37	0.6
70	0	0	0.19	0.32	0.46	0.73
80	0	0.02	0.22	0.35	0.56	0.77
90	0	0.02	0.23	0.37	0.6	0.83
100	0	0.03	0.23	0.39	0.61	0.87

Table 24. Canadian update model projection results for the probability of a decline in adult female abundance of 10% or more, for a range of catch levels, assuming the catch composition of 2002 (higher proportion of adult females).

Projection Year	**Catch Levels**					
	0	**500**	**1000**	**1500**	**2000**	**2500**
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0.01
33	0	0	0	0	0	0.02
34	0	0	0	0	0	0.05
35	0	0	0	0	0	0.15
36	0	0	0	0	0.01	0.2
37	0	0	0	0	0.02	0.22
38	0	0	0	0	0.04	0.23
39	0	0	0	0	0.07	0.24
40	0	0	0	0	0.15	0.28
41	0	0	0	0	0.19	0.31
42	0	0	0	0.01	0.22	0.34
43	0	0	0	0.02	0.22	0.34
44	0	0	0	0.03	0.23	0.36
45	0	0	0	0.05	0.23	0.38
46	0	0	0	0.07	0.25	0.4
47	0	0	0	0.11	0.28	0.41
48	0	0	0	0.16	0.29	0.41
49	0	0	0	0.19	0.31	0.45
50	0	0	0	0.21	0.32	0.47
60	0	0	0.11	0.28	0.41	0.67
70	0	0	0.21	0.34	0.51	0.74
80	0	0.02	0.22	0.36	0.6	0.8
90	0	0.03	0.23	0.37	0.61	0.87
100	0	0.04	0.24	0.39	0.62	0.87

Table 25. Canadian update model projection results for the probability of exceeding F_{MSY} at an assumed r of 0.042, for a range of catch levels, assuming the catch composition of 2002 (higher proportion of adult females).

Projection Year	**Catch Levels**					
	0	**500**	**1000**	**1500**	**2000**	**2500**
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0.01
47	0	0	0	0	0	0.03
48	0	0	0	0	0	0.06
49	0	0	0	0	0	0.15
50	0	0	0	0	0	0.21
60	0	0	0	0.05	0.24	0.4
70	0	0	0.02	0.23	0.37	0.61
80	0	0	0.15	0.3	0.46	0.74
90	0	0.01	0.22	0.35	0.56	0.78
100	0	0.02	0.23	0.37	0.6	0.84

Table 26. Canadian update model projection results for the probability of exceeding F_{lim}, for a range of catch levels, assuming the catch composition of 2002 (higher proportion of adult females).

Projection Year	**Catch Levels**					
	0	**500**	**1000**	**1500**	**2000**	**2500**
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0.02
35	0	0	0	0	0	0.05
36	0	0	0	0	0	0.11
37	0	0	0	0	0	0.19
38	0	0	0	0	0	0.22
39	0	0	0	0	0.02	0.23
40	0	0	0	0	0.04	0.24
41	0	0	0	0	0.06	0.28
42	0	0	0	0	0.14	0.3
43	0	0	0	0	0.19	0.32
44	0	0	0	0	0.21	0.34
45	0	0	0	0.01	0.22	0.35
46	0	0	0	0.02	0.23	0.37
47	0	0	0	0.03	0.23	0.39
48	0	0	0	0.05	0.24	0.41
49	0	0	0	0.06	0.28	0.41
50	0	0	0	0.11	0.29	0.45
60	0	0	0.05	0.24	0.41	0.65
70	0	0	0.19	0.32	0.48	0.74
80	0	0.02	0.22	0.35	0.58	0.8
90	0	0.02	0.23	0.37	0.61	0.86
100	0	0.03	0.23	0.39	0.61	0.87

Table 27. Proxy population (US winter stock abundance) model projection results for the probability of a decline in total abundance of 10% or more, for a range of catch levels, assuming the catch composition of 2010.

Projection Year	Catch Levels													
	8500	**9000**	**9500**	**10000**	**10500**	**11000**	**11500**	**12000**	**12500**	**13000**	**13500**	**14000**	**14500**	**15000**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02
26	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
27	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02
28	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02
29	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.02	0.05
30	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.04	0.07
31	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.06	0.12
32	0	0	0	0	0	0	0	0.01	0.02	0.02	0.02	0.05	0.09	0.13
33	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.06	0.12	0.13
34	0	0	0	0	0	0	0.01	0.02	0.02	0.02	0.05	0.09	0.13	0.13
35	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.06	0.12	0.13	0.14
36	0	0	0	0	0	0.01	0.02	0.02	0.04	0.04	0.09	0.13	0.13	0.16
37	0	0	0	0	0	0.02	0.02	0.02	0.06	0.06	0.12	0.13	0.14	0.18
38	0	0	0	0	0	0.02	0.02	0.02	0.07	0.07	0.12	0.13	0.16	0.2
39	0	0	0	0	0.01	0.02	0.02	0.02	0.1	0.1	0.13	0.14	0.17	0.2
40	0	0	0	0	0.02	0.02	0.02	0.02	0.12	0.12	0.13	0.14	0.19	0.22
41	0	0	0	0	0.02	0.02	0.02	0.02	0.12	0.12	0.13	0.14	0.2	0.24
42	0	0	0	0	0.02	0.02	0.02	0.03	0.13	0.13	0.14	0.17	0.2	0.25
43	0	0	0	0.01	0.02	0.02	0.02	0.04	0.13	0.13	0.14	0.18	0.2	0.26
44	0	0	0	0.01	0.02	0.02	0.02	0.06	0.13	0.13	0.14	0.19	0.23	0.28
45	0	0	0	0.02	0.02	0.02	0.02	0.07	0.13	0.13	0.15	0.2	0.24	0.29
46	0	0	0	0.02	0.02	0.02	0.03	0.07	0.14	0.14	0.16	0.2	0.24	0.3
47	0	0	0	0.02	0.02	0.02	0.03	0.09	0.14	0.14	0.17	0.2	0.26	0.32
48	0	0	0	0.02	0.02	0.02	0.03	0.1	0.14	0.14	0.18	0.21	0.27	0.32
49	0	0	0.01	0.02	0.02	0.02	0.04	0.11	0.14	0.14	0.19	0.23	0.27	0.34
50	0	0	0.01	0.02	0.02	0.02	0.05	0.11	0.15	0.15	0.19	0.24	0.28	0.35
60	0	0.01	0.02	0.02	0.02	0.03	0.11	0.13	0.19	0.19	0.23	0.27	0.35	0.41
70	0	0.02	0.02	0.02	0.02	0.07	0.12	0.14	0.2	0.2	0.26	0.3	0.37	0.45
80	0	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.22	0.22	0.26	0.32	0.37	0.45
90	0	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.22	0.22	0.27	0.33	0.39	0.46
100	0	0.02	0.02	0.02	0.03	0.09	0.13	0.15	0.22	0.22	0.27	0.33	0.39	0.47

Table 28. Proxy population (US winter stock abundance) model projection results for the probability of a decline in adult female abundance of 10% or more, for a range of catch levels, assuming the catch composition of 2010.

Projection Year	Catch Levels													
	8500	9000	9500	10000	10500	11000	11500	12000	12500	13000	13500	14000	14500	15000
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02
14	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
15	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02
16	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.03
17	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.02	0.05
18	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.04	0.06
19	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.03	0.06	0.12
20	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.06	0.1	0.13
21	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.04	0.06	0.12	0.13
22	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.06	0.12	0.13	0.13
23	0	0	0	0	0	0.01	0.02	0.02	0.05	0.05	0.07	0.12	0.13	0.15
24	0	0	0	0	0	0.02	0.02	0.02	0.06	0.06	0.11	0.13	0.13	0.16
25	0	0	0	0	0	0.02	0.02	0.02	0.06	0.06	0.12	0.13	0.13	0.19
26	0	0	0	0	0.01	0.02	0.02	0.02	0.09	0.09	0.13	0.13	0.16	0.19
27	0	0	0	0	0.02	0.02	0.02	0.02	0.12	0.12	0.13	0.13	0.17	0.21
28	0	0	0	0	0.02	0.02	0.02	0.02	0.12	0.12	0.13	0.14	0.19	0.21
29	0	0	0	0	0.02	0.02	0.02	0.03	0.13	0.13	0.13	0.16	0.2	0.24
30	0	0	0	0.01	0.02	0.02	0.02	0.05	0.13	0.13	0.13	0.17	0.2	0.25
31	0	0	0	0.02	0.02	0.02	0.02	0.06	0.13	0.13	0.14	0.18	0.21	0.26
32	0	0	0	0.02	0.02	0.02	0.02	0.06	0.13	0.13	0.14	0.2	0.23	0.27
33	0	0	0	0.02	0.02	0.02	0.03	0.07	0.13	0.13	0.15	0.2	0.24	0.29
34	0	0	0	0.02	0.02	0.02	0.03	0.09	0.14	0.14	0.17	0.2	0.25	0.31
35	0	0	0.01	0.02	0.02	0.02	0.03	0.1	0.14	0.14	0.17	0.2	0.25	0.32
36	0	0	0.01	0.02	0.02	0.02	0.04	0.11	0.14	0.14	0.18	0.21	0.26	0.32
37	0	0	0.01	0.02	0.02	0.02	0.06	0.11	0.14	0.14	0.19	0.22	0.28	0.32
38	0	0	0.02	0.02	0.02	0.02	0.07	0.12	0.14	0.14	0.19	0.24	0.28	0.35
39	0	0	0.02	0.02	0.02	0.02	0.07	0.12	0.15	0.15	0.2	0.24	0.29	0.36
40	0	0	0.02	0.02	0.02	0.03	0.07	0.12	0.15	0.15	0.2	0.24	0.3	0.36
41	0	0	0.02	0.02	0.02	0.03	0.08	0.13	0.16	0.16	0.2	0.24	0.3	0.37
42	0	0	0.02	0.02	0.02	0.03	0.09	0.13	0.17	0.17	0.2	0.26	0.31	0.38
43	0	0	0.02	0.02	0.02	0.03	0.09	0.13	0.17	0.17	0.2	0.27	0.32	0.38
44	0	0	0.02	0.02	0.02	0.03	0.1	0.13	0.18	0.18	0.21	0.27	0.32	0.38
45	0	0	0.02	0.02	0.02	0.03	0.1	0.13	0.19	0.19	0.21	0.27	0.33	0.38
46	0	0.01	0.02	0.02	0.02	0.03	0.11	0.13	0.19	0.19	0.22	0.27	0.34	0.38
47	0	0.01	0.02	0.02	0.02	0.03	0.11	0.13	0.19	0.19	0.22	0.27	0.35	0.4
48	0	0.01	0.02	0.02	0.02	0.04	0.11	0.13	0.19	0.19	0.24	0.28	0.35	0.41
49	0	0.01	0.02	0.02	0.02	0.05	0.11	0.14	0.19	0.19	0.24	0.28	0.36	0.42
50	0	0.01	0.02	0.02	0.02	0.05	0.11	0.14	0.19	0.19	0.24	0.28	0.36	0.42
60	0	0.02	0.02	0.02	0.03	0.07	0.12	0.14	0.2	0.2	0.26	0.31	0.37	0.45
70	0	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.22	0.22	0.26	0.32	0.37	0.45
80	0	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.22	0.22	0.27	0.33	0.39	0.46
90	0	0.02	0.02	0.02	0.03	0.09	0.13	0.15	0.22	0.22	0.27	0.33	0.39	0.47
100	0	0.02	0.02	0.02	0.03	0.1	0.13	0.15	0.22	0.22	0.27	0.33	0.39	0.47

Table 29. Proxy population (US winter stock abundance) model projection results for the probability of exceeding F_{MSY} at an assumed r of 0.042, for a range of catch levels, assuming the catch composition of 2010.

Projection Year	Catch Levels													
	8500	**9000**	**9500**	**10000**	**10500**	**11000**	**11500**	**12000**	**12500**	**13000**	**13500**	**14000**	**14500**	**15000**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02
27	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
28	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.02
29	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02
30	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02
31	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.02	0.06
32	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.05	0.09
33	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.07	0.12
34	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.06	0.12	0.14
35	0	0	0	0	0	0	0	0.02	0.02	0.02	0.03	0.07	0.12	0.13
36	0	0	0	0	0	0	0.01	0.02	0.02	0.02	0.06	0.12	0.14	0.14
37	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.07	0.12	0.13	0.17
38	0	0	0	0	0	0.01	0.02	0.02	0.05	0.05	0.1	0.14	0.15	0.18
39	0	0	0	0	0	0.02	0.02	0.02	0.06	0.06	0.12	0.13	0.14	0.2
40	0	0	0	0	0	0.02	0.02	0.02	0.08	0.08	0.13	0.13	0.17	0.21
41	0	0	0	0	0.01	0.02	0.02	0.02	0.1	0.1	0.14	0.14	0.18	0.21
42	0	0	0	0	0.02	0.02	0.02	0.02	0.12	0.12	0.13	0.14	0.2	0.24
43	0	0	0	0	0.02	0.02	0.02	0.03	0.12	0.12	0.13	0.18	0.2	0.26
44	0	0	0	0	0.02	0.02	0.02	0.03	0.13	0.13	0.14	0.17	0.2	0.26
45	0	0	0	0.01	0.02	0.02	0.02	0.04	0.14	0.14	0.14	0.19	0.22	0.28
46	0	0	0	0.01	0.02	0.02	0.02	0.06	0.13	0.13	0.14	0.19	0.25	0.29
47	0	0	0	0.02	0.02	0.02	0.02	0.07	0.13	0.13	0.15	0.2	0.25	0.3
48	0	0	0	0.02	0.02	0.02	0.03	0.08	0.14	0.14	0.17	0.2	0.25	0.31
49	0	0	0	0.02	0.02	0.02	0.03	0.09	0.14	0.14	0.17	0.2	0.26	0.32
50	0	0	0	0.02	0.02	0.02	0.03	0.1	0.14	0.14	0.19	0.21	0.27	0.32
60	0	0	0.02	0.02	0.02	0.03	0.1	0.14	0.19	0.19	0.22	0.27	0.34	0.4
70	0	0.01	0.02	0.02	0.02	0.06	0.12	0.14	0.19	0.19	0.26	0.3	0.37	0.45
80	0	0.02	0.02	0.02	0.03	0.08	0.13	0.14	0.22	0.22	0.26	0.32	0.37	0.45
90	0	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.22	0.22	0.26	0.32	0.38	0.46
100	0	0.02	0.02	0.02	0.03	0.09	0.13	0.15	0.22	0.22	0.27	0.33	0.39	0.46

Table 30. Proxy population (US winter stock abundance) model projection results for the probability of exceeding F_{lim}, for a range of catch levels, assuming the catch composition of 2010.

Projection Year	Catch Levels													
	8500	**9000**	**9500**	**10000**	**10500**	**11000**	**11500**	**12000**	**12500**	**13000**	**13500**	**14000**	**14500**	**15000**
1	0	0	0	0	0	0	0.01	0.01	0.03	0.03	0.03	0.03	0.04	0.08
2	0	0	0.01	0.02	0.03	0.03	0.04	0.04	0.11	0.11	0.16	0.2	0.3	0.37
3	0.01	0.03	0.03	0.04	0.04	0.06	0.12	0.17	0.31	0.31	0.36	0.41	0.44	0.47
4	0.03	0.03	0.04	0.05	0.12	0.18	0.19	0.25	0.4	0.4	0.44	0.47	0.52	0.58
5	0.04	0.04	0.06	0.13	0.17	0.21	0.23	0.36	0.45	0.45	0.49	0.53	0.59	0.61
6	0.04	0.06	0.11	0.17	0.19	0.22	0.3	0.39	0.48	0.48	0.52	0.57	0.59	0.66
7	0.04	0.07	0.13	0.17	0.21	0.22	0.35	0.4	0.48	0.48	0.54	0.59	0.61	0.67
8	0.05	0.08	0.13	0.17	0.21	0.23	0.33	0.4	0.5	0.5	0.56	0.59	0.63	0.67
9	0.05	0.08	0.13	0.16	0.19	0.22	0.31	0.41	0.5	0.5	0.56	0.59	0.63	0.67
10	0.04	0.07	0.13	0.16	0.19	0.21	0.3	0.41	0.5	0.5	0.56	0.59	0.63	0.67
11	0.04	0.07	0.13	0.15	0.18	0.21	0.28	0.4	0.5	0.5	0.54	0.59	0.62	0.66
12	0.04	0.06	0.12	0.13	0.18	0.2	0.26	0.33	0.5	0.5	0.54	0.57	0.6	0.65
13	0.03	0.06	0.12	0.13	0.16	0.19	0.25	0.31	0.49	0.49	0.54	0.57	0.6	0.64
14	0.02	0.06	0.11	0.13	0.15	0.18	0.25	0.29	0.48	0.48	0.53	0.56	0.6	0.64
15	0.02	0.05	0.1	0.13	0.14	0.18	0.22	0.27	0.48	0.48	0.52	0.55	0.6	0.63
16	0.02	0.04	0.06	0.13	0.13	0.17	0.21	0.27	0.46	0.46	0.51	0.54	0.59	0.62
17	0.02	0.03	0.06	0.12	0.13	0.16	0.2	0.26	0.43	0.43	0.51	0.54	0.58	0.61
18	0.02	0.02	0.06	0.12	0.13	0.15	0.2	0.25	0.38	0.38	0.5	0.54	0.57	0.6
19	0.02	0.02	0.06	0.12	0.13	0.15	0.19	0.23	0.36	0.36	0.49	0.53	0.57	0.6
20	0.02	0.02	0.05	0.11	0.13	0.13	0.19	0.23	0.36	0.36	0.48	0.53	0.56	0.6
21	0.02	0.02	0.05	0.09	0.13	0.13	0.18	0.21	0.34	0.34	0.45	0.53	0.55	0.58
22	0.02	0.02	0.02	0.08	0.13	0.13	0.17	0.21	0.32	0.32	0.39	0.53	0.55	0.58
23	0.02	0.02	0.02	0.07	0.12	0.13	0.16	0.21	0.32	0.32	0.39	0.52	0.55	0.58
24	0.02	0.02	0.02	0.06	0.12	0.13	0.16	0.2	0.31	0.31	0.38	0.5	0.55	0.58
25	0.02	0.02	0.02	0.06	0.12	0.13	0.15	0.2	0.31	0.31	0.37	0.49	0.55	0.57
26	0.02	0.02	0.02	0.06	0.12	0.13	0.14	0.2	0.31	0.31	0.37	0.47	0.54	0.57
27	0.02	0.02	0.02	0.06	0.11	0.13	0.14	0.2	0.29	0.29	0.36	0.42	0.54	0.56
28	0.02	0.02	0.02	0.04	0.11	0.13	0.14	0.19	0.29	0.29	0.34	0.42	0.54	0.56
29	0.02	0.02	0.02	0.03	0.1	0.13	0.14	0.19	0.28	0.28	0.34	0.42	0.54	0.55
30	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.18	0.28	0.28	0.34	0.4	0.54	0.55
31	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.17	0.27	0.27	0.32	0.39	0.53	0.55
32	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.17	0.27	0.27	0.32	0.39	0.52	0.55
33	0.02	0.02	0.02	0.03	0.08	0.13	0.14	0.17	0.26	0.26	0.32	0.38	0.52	0.55
34	0.02	0.02	0.02	0.03	0.07	0.12	0.14	0.17	0.26	0.26	0.32	0.38	0.5	0.55
35	0.02	0.02	0.02	0.02	0.07	0.12	0.14	0.16	0.26	0.26	0.31	0.38	0.48	0.55
36	0.01	0.02	0.02	0.02	0.07	0.12	0.14	0.15	0.25	0.25	0.3	0.38	0.45	0.55
37	0.01	0.02	0.02	0.02	0.07	0.12	0.14	0.15	0.25	0.25	0.3	0.37	0.44	0.55
38	0.01	0.02	0.02	0.02	0.07	0.12	0.14	0.15	0.25	0.25	0.3	0.37	0.44	0.54
39	0.01	0.02	0.02	0.02	0.06	0.11	0.14	0.15	0.24	0.24	0.3	0.37	0.44	0.54
40	0.01	0.02	0.02	0.02	0.06	0.11	0.14	0.15	0.24	0.24	0.3	0.37	0.44	0.54
41	0.01	0.02	0.02	0.02	0.06	0.11	0.14	0.15	0.24	0.24	0.3	0.37	0.44	0.54
42	0.01	0.02	0.02	0.02	0.05	0.11	0.14	0.15	0.24	0.24	0.29	0.36	0.43	0.54
43	0.01	0.02	0.02	0.02	0.05	0.11	0.14	0.15	0.24	0.24	0.29	0.36	0.43	0.54
44	0.01	0.02	0.02	0.02	0.04	0.11	0.14	0.15	0.24	0.24	0.29	0.36	0.42	0.54
45	0.01	0.02	0.02	0.02	0.03	0.11	0.14	0.15	0.24	0.24	0.28	0.36	0.42	0.54
46	0.01	0.02	0.02	0.02	0.03	0.11	0.14	0.15	0.24	0.24	0.28	0.36	0.42	0.54
47	0	0.02	0.02	0.02	0.03	0.11	0.14	0.15	0.23	0.23	0.27	0.36	0.42	0.53
48	0	0.02	0.02	0.02	0.03	0.11	0.14	0.15	0.23	0.23	0.27	0.36	0.42	0.53
49	0	0.02	0.02	0.02	0.03	0.11	0.14	0.15	0.23	0.23	0.27	0.36	0.42	0.53
50	0	0.02	0.02	0.02	0.03	0.11	0.14	0.15	0.23	0.23	0.27	0.36	0.42	0.53
60	0	0.02	0.02	0.02	0.03	0.1	0.14	0.15	0.22	0.22	0.27	0.35	0.4	0.52
70	0	0.02	0.02	0.02	0.03	0.1	0.14	0.15	0.22	0.22	0.27	0.33	0.4	0.51
80	0	0.02	0.02	0.02	0.03	0.1	0.14	0.15	0.22	0.22	0.27	0.33	0.39	0.49
90	0	0.02	0.02	0.02	0.03	0.1	0.14	0.15	0.22	0.22	0.27	0.33	0.39	0.49
100	0	0.02	0.02	0.02	0.03	0.1	0.14	0.15	0.22	0.22	0.27	0.33	0.39	0.49

Table 31. Proxy population (US winter stock abundance) model projection results for the probability of a decline in total abundance of 10% or more, for a range of catch levels, assuming the catch composition of 2007 (higher proportion of adult females).

Projection Year	Catch Levels													
	0	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**	**5500**	**6000**	**6500**	**7000**	**7500**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
14	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02
15	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02
16	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.05
17	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.05	0.08
18	0	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.05	0.07	0.12
19	0	0	0	0	0	0	0	0.02	0.02	0.02	0.03	0.06	0.12	0.13
20	0	0	0	0	0	0	0.02	0.02	0.02	0.02	0.06	0.12	0.13	0.13
21	0	0	0	0	0	0.01	0.02	0.02	0.02	0.05	0.09	0.13	0.13	0.16
22	0	0	0	0	0	0.02	0.02	0.02	0.02	0.06	0.12	0.13	0.13	0.19
23	0	0	0	0	0	0.02	0.02	0.02	0.05	0.09	0.13	0.13	0.16	0.21
24	0	0	0	0	0.02	0.02	0.02	0.02	0.06	0.12	0.13	0.14	0.19	0.22
25	0	0	0	0	0.02	0.02	0.02	0.02	0.07	0.12	0.13	0.16	0.21	0.26
26	0	0	0	0	0.02	0.02	0.02	0.05	0.1	0.13	0.14	0.19	0.21	0.27
27	0	0	0	0.01	0.02	0.02	0.02	0.06	0.12	0.13	0.14	0.2	0.24	0.31
28	0	0	0	0.02	0.02	0.02	0.02	0.07	0.12	0.13	0.17	0.21	0.26	0.32
29	0	0	0	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.18	0.21	0.27	0.35
30	0	0	0	0.02	0.02	0.02	0.04	0.11	0.13	0.14	0.2	0.24	0.31	0.37
31	0	0	0	0.02	0.02	0.02	0.06	0.12	0.13	0.15	0.2	0.25	0.32	0.39
32	0	0	0	0.02	0.02	0.02	0.07	0.12	0.13	0.17	0.2	0.27	0.32	0.41
33	0	0	0.01	0.02	0.02	0.02	0.07	0.13	0.14	0.18	0.22	0.28	0.34	0.42
34	0	0	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.19	0.24	0.29	0.37	0.48
35	0	0	0.02	0.02	0.02	0.03	0.1	0.13	0.14	0.2	0.24	0.31	0.37	0.5
36	0	0	0.02	0.02	0.02	0.03	0.11	0.13	0.15	0.2	0.25	0.32	0.39	0.52
37	0	0	0.02	0.02	0.02	0.05	0.11	0.13	0.16	0.2	0.26	0.32	0.4	0.54
38	0	0	0.02	0.02	0.02	0.06	0.12	0.14	0.17	0.2	0.27	0.35	0.42	0.54
39	0	0	0.02	0.02	0.02	0.07	0.12	0.14	0.17	0.21	0.28	0.35	0.43	0.54
40	0	0	0.02	0.02	0.02	0.07	0.12	0.14	0.19	0.23	0.28	0.36	0.43	0.55
41	0	0	0.02	0.02	0.02	0.07	0.13	0.14	0.19	0.24	0.29	0.37	0.48	0.55
42	0	0	0.02	0.02	0.02	0.08	0.13	0.14	0.19	0.24	0.3	0.38	0.5	0.55
43	0	0.01	0.02	0.02	0.03	0.09	0.13	0.14	0.19	0.24	0.3	0.38	0.53	0.55
44	0	0.01	0.02	0.02	0.03	0.09	0.13	0.15	0.2	0.24	0.31	0.38	0.53	0.55
45	0	0.01	0.02	0.02	0.03	0.1	0.13	0.15	0.2	0.26	0.32	0.4	0.53	0.55
46	0	0.01	0.02	0.02	0.03	0.1	0.13	0.15	0.2	0.27	0.34	0.4	0.53	0.57
47	0	0.01	0.02	0.02	0.03	0.11	0.14	0.15	0.2	0.27	0.34	0.41	0.54	0.58
48	0	0.01	0.02	0.02	0.03	0.11	0.14	0.15	0.2	0.27	0.35	0.42	0.54	0.58
49	0	0.02	0.02	0.02	0.03	0.11	0.14	0.15	0.21	0.27	0.35	0.43	0.54	0.58
50	0	0.02	0.02	0.02	0.04	0.11	0.14	0.16	0.21	0.27	0.35	0.43	0.54	0.58
60	0	0.02	0.02	0.02	0.07	0.12	0.15	0.19	0.25	0.31	0.38	0.52	0.55	0.59
70	0	0.02	0.02	0.03	0.08	0.13	0.15	0.19	0.26	0.33	0.39	0.53	0.58	0.61
80	0	0.02	0.02	0.03	0.09	0.14	0.15	0.2	0.26	0.33	0.4	0.53	0.58	0.61
90	0	0.02	0.02	0.03	0.09	0.14	0.15	0.2	0.27	0.33	0.41	0.53	0.58	0.61
100	0	0.02	0.02	0.03	0.09	0.14	0.15	0.21	0.27	0.33	0.41	0.53	0.58	0.62

Table 32. Proxy population (US winter stock abundance) model projection results for the probability of a decline in adult female abundance of 10% or more, for a range of catch levels, assuming the catch composition of 2007 (higher proportion of adult females).

Projection Year	Catch Levels													
	0	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
1	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.08	0.08	0.08	0.1
2	0.14	0.18	0.2	0.22	0.26	0.3	0.32	0.35	0.36	0.36	0.38	0.39	0.39	0.41
3	0.3	0.36	0.36	0.38	0.41	0.43	0.43	0.44	0.46	0.47	0.49	0.49	0.52	0.54
4	0.36	0.43	0.44	0.44	0.47	0.48	0.49	0.52	0.54	0.56	0.59	0.59	0.62	0.64
5	0.36	0.44	0.46	0.48	0.49	0.52	0.55	0.57	0.59	0.6	0.63	0.65	0.68	0.68
6	0.36	0.45	0.48	0.48	0.51	0.54	0.57	0.59	0.59	0.62	0.66	0.68	0.71	0.74
7	0.3	0.45	0.47	0.48	0.52	0.56	0.58	0.59	0.61	0.65	0.67	0.7	0.72	0.76
8	0.23	0.42	0.47	0.48	0.51	0.55	0.57	0.59	0.62	0.64	0.67	0.7	0.73	0.77
9	0.21	0.4	0.45	0.47	0.5	0.54	0.57	0.59	0.61	0.63	0.67	0.7	0.73	0.77
10	0.19	0.31	0.41	0.47	0.49	0.52	0.56	0.58	0.6	0.63	0.66	0.69	0.73	0.75
11	0.18	0.23	0.33	0.43	0.47	0.5	0.54	0.57	0.6	0.63	0.65	0.68	0.72	0.74
12	0.15	0.24	0.29	0.37	0.46	0.49	0.54	0.56	0.6	0.6	0.65	0.68	0.72	0.74
13	0.13	0.21	0.26	0.31	0.41	0.48	0.51	0.54	0.57	0.6	0.64	0.67	0.7	0.74
14	0.13	0.19	0.23	0.27	0.35	0.45	0.51	0.54	0.56	0.6	0.63	0.67	0.69	0.73
15	0.1	0.17	0.21	0.26	0.3	0.38	0.48	0.53	0.54	0.59	0.61	0.67	0.68	0.72
16	0.06	0.15	0.19	0.24	0.28	0.34	0.46	0.51	0.54	0.57	0.6	0.64	0.67	0.7
17	0.06	0.13	0.18	0.2	0.26	0.32	0.39	0.5	0.54	0.57	0.6	0.64	0.67	0.7
18	0.02	0.13	0.15	0.2	0.25	0.29	0.36	0.49	0.53	0.56	0.59	0.63	0.67	0.7
19	0.02	0.13	0.13	0.18	0.22	0.28	0.34	0.44	0.52	0.55	0.58	0.61	0.67	0.69
20	0.02	0.13	0.13	0.16	0.21	0.25	0.31	0.38	0.51	0.54	0.57	0.61	0.66	0.68
21	0.02	0.12	0.13	0.16	0.19	0.24	0.3	0.37	0.49	0.53	0.57	0.6	0.66	0.68
22	0.02	0.1	0.13	0.13	0.19	0.23	0.29	0.35	0.48	0.53	0.56	0.6	0.66	0.68
23	0.02	0.08	0.13	0.13	0.18	0.21	0.26	0.34	0.42	0.53	0.55	0.58	0.65	0.68
24	0.02	0.07	0.12	0.13	0.16	0.21	0.26	0.32	0.4	0.53	0.55	0.58	0.64	0.68
25	0.02	0.06	0.12	0.13	0.15	0.2	0.25	0.32	0.38	0.51	0.55	0.58	0.62	0.68
26	0.02	0.03	0.11	0.13	0.14	0.2	0.25	0.31	0.37	0.49	0.55	0.58	0.61	0.68
27	0.02	0.03	0.09	0.13	0.14	0.19	0.23	0.29	0.37	0.48	0.54	0.58	0.61	0.67
28	0.01	0.02	0.07	0.13	0.14	0.18	0.22	0.28	0.36	0.43	0.54	0.57	0.61	0.67
29	0	0.02	0.07	0.12	0.14	0.17	0.21	0.28	0.34	0.42	0.54	0.57	0.6	0.66
30	0	0.02	0.06	0.12	0.14	0.17	0.2	0.26	0.34	0.41	0.54	0.56	0.6	0.66
31	0	0.02	0.05	0.11	0.13	0.16	0.2	0.26	0.32	0.4	0.54	0.55	0.59	0.66
32	0	0.02	0.03	0.11	0.13	0.15	0.2	0.26	0.32	0.39	0.53	0.55	0.59	0.66
33	0	0.02	0.03	0.1	0.13	0.15	0.2	0.24	0.32	0.38	0.53	0.55	0.58	0.66
34	0	0.02	0.03	0.1	0.13	0.14	0.19	0.24	0.3	0.38	0.52	0.55	0.58	0.66
35	0	0.02	0.03	0.09	0.13	0.14	0.19	0.24	0.3	0.38	0.52	0.55	0.58	0.65
36	0	0.02	0.02	0.08	0.13	0.14	0.19	0.24	0.3	0.38	0.5	0.55	0.58	0.65
37	0	0.02	0.02	0.07	0.13	0.14	0.19	0.24	0.29	0.37	0.49	0.55	0.58	0.65
38	0	0.02	0.02	0.07	0.13	0.14	0.19	0.24	0.29	0.37	0.47	0.55	0.58	0.65
39	0	0.02	0.02	0.07	0.12	0.14	0.18	0.22	0.28	0.36	0.44	0.55	0.58	0.65
40	0	0.02	0.02	0.07	0.12	0.14	0.18	0.22	0.28	0.36	0.44	0.55	0.58	0.65
41	0	0.02	0.02	0.06	0.12	0.14	0.18	0.22	0.28	0.36	0.44	0.55	0.58	0.64
42	0	0.02	0.02	0.06	0.12	0.14	0.18	0.22	0.27	0.36	0.44	0.54	0.58	0.64
43	0	0.02	0.02	0.05	0.11	0.14	0.18	0.22	0.27	0.36	0.43	0.54	0.58	0.63
44	0	0.02	0.02	0.04	0.11	0.14	0.17	0.21	0.27	0.36	0.43	0.54	0.58	0.63
45	0	0.02	0.02	0.04	0.11	0.14	0.16	0.21	0.27	0.36	0.43	0.54	0.58	0.63
46	0	0.02	0.02	0.04	0.11	0.14	0.16	0.21	0.27	0.35	0.43	0.54	0.58	0.62
47	0	0.02	0.02	0.04	0.11	0.14	0.15	0.21	0.27	0.35	0.43	0.54	0.58	0.62
48	0	0.02	0.02	0.04	0.11	0.14	0.15	0.21	0.27	0.35	0.43	0.54	0.58	0.62
49	0	0.02	0.02	0.04	0.11	0.14	0.15	0.21	0.27	0.35	0.43	0.54	0.58	0.62
50	0	0.02	0.02	0.03	0.11	0.14	0.15	0.21	0.27	0.35	0.43	0.54	0.58	0.62
60	0	0.02	0.02	0.03	0.1	0.14	0.15	0.21	0.27	0.35	0.42	0.53	0.58	0.62
70	0	0.02	0.02	0.03	0.1	0.14	0.15	0.21	0.27	0.35	0.41	0.53	0.58	0.62
80	0	0.02	0.02	0.03	0.1	0.14	0.15	0.21	0.27	0.34	0.41	0.53	0.58	0.62
90	0	0.02	0.02	0.03	0.1	0.14	0.15	0.21	0.27	0.33	0.41	0.53	0.58	0.62
100	0	0.02	0.02	0.03	0.1	0.14	0.15	0.21	0.27	0.33	0.41	0.53	0.58	0.62

Table 33. Proxy population (US winter stock abundance) model projection results for the probability of exceeding F_{MSY} at an assumed r of 0.042, for a range of catch levels, assuming the catch composition of 2007 (higher proportion of adult females).

Projection Year	Catch Levels													
	0	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**	**5500**	**6000**	**6500**	**7000**	**7500**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02
28	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
29	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02
30	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.04
31	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.06
32	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.06	0.12
33	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.05	0.1	0.13
34	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.06	0.13	0.13
35	0	0	0	0	0	0	0	0.02	0.02	0.02	0.06	0.12	0.13	0.16
36	0	0	0	0	0	0	0	0.02	0.02	0.02	0.07	0.13	0.13	0.19
37	0	0	0	0	0	0	0.02	0.02	0.02	0.05	0.12	0.13	0.16	0.21
38	0	0	0	0	0	0	0.02	0.02	0.02	0.07	0.13	0.13	0.18	0.21
39	0	0	0	0	0	0.02	0.02	0.02	0.03	0.09	0.13	0.14	0.2	0.25
40	0	0	0	0	0	0.02	0.02	0.02	0.07	0.12	0.13	0.16	0.21	0.26
41	0	0	0	0	0	0.02	0.02	0.02	0.07	0.13	0.14	0.19	0.24	0.31
42	0	0	0	0	0.01	0.02	0.02	0.04	0.1	0.13	0.15	0.2	0.25	0.32
43	0	0	0	0	0.02	0.02	0.02	0.06	0.12	0.13	0.17	0.21	0.27	0.36
44	0	0	0	0	0.02	0.02	0.02	0.07	0.12	0.14	0.19	0.23	0.3	0.38
45	0	0	0	0	0.02	0.02	0.03	0.08	0.13	0.14	0.2	0.25	0.31	0.4
46	0	0	0	0.01	0.02	0.02	0.03	0.1	0.13	0.16	0.2	0.26	0.34	0.41
47	0	0	0	0.02	0.02	0.02	0.06	0.12	0.13	0.17	0.22	0.28	0.36	0.46
48	0	0	0	0.02	0.02	0.02	0.07	0.12	0.14	0.18	0.22	0.28	0.37	0.5
49	0	0	0	0.02	0.02	0.02	0.07	0.13	0.14	0.19	0.24	0.31	0.38	0.52
50	0	0	0	0.02	0.02	0.03	0.08	0.13	0.14	0.2	0.25	0.31	0.41	0.53
60	0	0	0.02	0.02	0.03	0.1	0.13	0.15	0.2	0.27	0.34	0.41	0.53	0.58
70	0	0.02	0.02	0.02	0.06	0.12	0.14	0.19	0.24	0.29	0.38	0.51	0.55	0.59
80	0	0.02	0.02	0.02	0.07	0.13	0.15	0.19	0.26	0.31	0.39	0.53	0.58	0.61
90	0	0.02	0.02	0.03	0.09	0.14	0.15	0.19	0.26	0.33	0.4	0.53	0.58	0.61
100	0	0.02	0.02	0.03	0.09	0.14	0.15	0.2	0.27	0.33	0.41	0.53	0.58	0.61

Table 34. Proxy population (US winter stock abundance) model projection results for the probability of exceeding F_{lim}, for a range of catch levels, assuming the catch composition of 2007 (higher proportion of adult females).

Projection Year	Catch Levels													
	0	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**	**5500**	**6000**	**6500**	**7000**	**7500**
1	0	0	0	0.01	0.03	0.03	0.03	0.04	0.04	0.11	0.13	0.22	0.34	0.39
2	0	0.03	0.03	0.04	0.04	0.1	0.16	0.22	0.36	0.39	0.42	0.48	0.52	0.56
3	0.01	0.04	0.06	0.14	0.18	0.27	0.36	0.41	0.46	0.49	0.55	0.62	0.67	0.76
4	0.03	0.1	0.16	0.2	0.32	0.36	0.44	0.47	0.53	0.59	0.65	0.69	0.79	0.81
5	0.03	0.16	0.2	0.23	0.36	0.44	0.48	0.53	0.59	0.64	0.68	0.77	0.81	0.84
6	0.04	0.17	0.21	0.28	0.39	0.46	0.49	0.57	0.59	0.66	0.71	0.79	0.82	0.87
7	0.04	0.17	0.21	0.28	0.4	0.47	0.51	0.57	0.61	0.67	0.71	0.79	0.82	0.88
8	0.04	0.17	0.21	0.27	0.4	0.47	0.51	0.57	0.62	0.66	0.71	0.79	0.82	0.87
9	0.04	0.16	0.21	0.26	0.39	0.47	0.51	0.57	0.6	0.66	0.71	0.77	0.82	0.86
10	0.03	0.15	0.19	0.25	0.35	0.47	0.5	0.57	0.6	0.65	0.71	0.75	0.82	0.84
11	0.03	0.14	0.18	0.23	0.3	0.43	0.5	0.55	0.6	0.64	0.68	0.74	0.81	0.83
12	0.02	0.13	0.17	0.21	0.28	0.42	0.48	0.54	0.6	0.63	0.68	0.73	0.78	0.83
13	0.02	0.13	0.15	0.19	0.26	0.35	0.48	0.54	0.57	0.6	0.67	0.72	0.76	0.81
14	0.02	0.12	0.14	0.18	0.25	0.32	0.46	0.51	0.55	0.6	0.67	0.7	0.75	0.8
15	0.02	0.12	0.13	0.17	0.22	0.3	0.43	0.51	0.54	0.6	0.64	0.69	0.75	0.77
16	0.02	0.1	0.13	0.16	0.21	0.27	0.35	0.5	0.54	0.59	0.63	0.67	0.75	0.76
17	0.02	0.07	0.13	0.15	0.2	0.26	0.34	0.47	0.54	0.57	0.61	0.67	0.7	0.75
18	0.02	0.06	0.13	0.13	0.18	0.25	0.32	0.44	0.53	0.57	0.6	0.67	0.7	0.75
19	0.02	0.06	0.12	0.13	0.18	0.23	0.3	0.38	0.52	0.55	0.6	0.66	0.69	0.75
20	0.01	0.05	0.12	0.13	0.17	0.21	0.28	0.37	0.5	0.55	0.59	0.65	0.68	0.75
21	0	0.04	0.11	0.13	0.16	0.21	0.26	0.35	0.49	0.55	0.58	0.64	0.68	0.72
22	0	0.02	0.09	0.13	0.14	0.2	0.26	0.34	0.48	0.53	0.58	0.61	0.68	0.72
23	0	0.02	0.07	0.13	0.14	0.19	0.25	0.32	0.41	0.53	0.57	0.61	0.68	0.7
24	0	0.02	0.07	0.13	0.13	0.19	0.24	0.31	0.4	0.53	0.56	0.61	0.66	0.7
25	0	0.02	0.06	0.12	0.13	0.18	0.23	0.31	0.38	0.53	0.55	0.59	0.66	0.7
26	0	0.02	0.06	0.12	0.13	0.18	0.22	0.29	0.37	0.52	0.55	0.58	0.66	0.69
27	0	0.02	0.03	0.12	0.13	0.17	0.21	0.28	0.37	0.49	0.55	0.58	0.66	0.68
28	0	0.02	0.03	0.11	0.13	0.17	0.2	0.27	0.35	0.47	0.55	0.58	0.64	0.68
29	0	0.02	0.03	0.1	0.13	0.15	0.2	0.27	0.34	0.43	0.54	0.58	0.63	0.68
30	0	0.02	0.03	0.09	0.13	0.14	0.2	0.26	0.34	0.42	0.54	0.58	0.63	0.68
31	0	0.02	0.02	0.09	0.13	0.14	0.2	0.25	0.32	0.41	0.54	0.58	0.61	0.68
32	0	0.02	0.02	0.07	0.13	0.14	0.2	0.25	0.32	0.41	0.54	0.58	0.6	0.68
33	0	0.02	0.02	0.07	0.13	0.14	0.2	0.25	0.32	0.4	0.54	0.58	0.6	0.68
34	0	0.02	0.02	0.07	0.13	0.14	0.19	0.24	0.3	0.4	0.53	0.57	0.6	0.67
35	0	0.02	0.02	0.07	0.12	0.14	0.19	0.24	0.3	0.39	0.53	0.56	0.6	0.67
36	0	0.02	0.02	0.07	0.12	0.14	0.19	0.24	0.3	0.39	0.53	0.56	0.6	0.67
37	0	0.02	0.02	0.07	0.12	0.14	0.19	0.24	0.29	0.39	0.53	0.56	0.6	0.67
38	0	0.02	0.02	0.07	0.12	0.14	0.19	0.24	0.29	0.39	0.53	0.56	0.59	0.67
39	0	0.02	0.02	0.06	0.12	0.14	0.19	0.23	0.28	0.39	0.53	0.56	0.59	0.67
40	0	0.02	0.02	0.06	0.12	0.14	0.18	0.23	0.28	0.39	0.53	0.56	0.6	0.67
41	0	0.02	0.02	0.06	0.12	0.14	0.18	0.23	0.3	0.39	0.53	0.56	0.6	0.67
42	0	0.02	0.02	0.06	0.12	0.14	0.19	0.22	0.29	0.39	0.53	0.56	0.6	0.66
43	0	0.02	0.02	0.06	0.12	0.14	0.19	0.22	0.29	0.39	0.52	0.56	0.6	0.66
44	0	0.02	0.02	0.06	0.12	0.15	0.18	0.23	0.29	0.39	0.52	0.56	0.6	0.66
45	0	0.02	0.02	0.06	0.12	0.14	0.18	0.23	0.29	0.38	0.51	0.54	0.59	0.66
46	0	0.02	0.02	0.05	0.12	0.14	0.18	0.22	0.29	0.38	0.51	0.54	0.59	0.66
47	0	0.02	0.02	0.05	0.12	0.14	0.18	0.22	0.28	0.37	0.49	0.54	0.59	0.66
48	0	0.02	0.02	0.05	0.12	0.14	0.17	0.21	0.28	0.37	0.49	0.54	0.59	0.66
49	0	0.02	0.02	0.05	0.11	0.14	0.17	0.21	0.28	0.37	0.48	0.54	0.59	0.66
50	0	0.02	0.02	0.05	0.1	0.14	0.17	0.21	0.27	0.37	0.46	0.54	0.59	0.66
60	0	0.02	0.02	0.03	0.1	0.14	0.16	0.21	0.27	0.36	0.44	0.53	0.58	0.65
70	0	0.02	0.02	0.03	0.1	0.14	0.15	0.21	0.27	0.35	0.42	0.53	0.58	0.62
80	0	0.02	0.02	0.03	0.1	0.14	0.15	0.21	0.27	0.35	0.41	0.53	0.58	0.62
90	0	0.02	0.02	0.03	0.1	0.14	0.15	0.21	0.27	0.34	0.41	0.53	0.58	0.62
100	0	0.02	0.02	0.03	0.1	0.14	0.15	0.21	0.27	0.33	0.41	0.53	0.58	0.62

Table 35. Conversion of sustainable catch levels (at P=0.5) to corresponding Total Allowable Catch (TAC) equivalents.

Projection Scenario	Total Catch	Proportions by Region		Catch by Region		Proportions Dead Discards		Adjusting for Dead Discards	
		US	Canada	US	Canada	US	Canada	US	Canada
catch ratio	47350	0.84	0.16	39774	7576	0.57	0.25	22671	1894
K ratio	49100	0.59	0.41	28969	20131	0.57	0.25	16512	5033

FIGURES

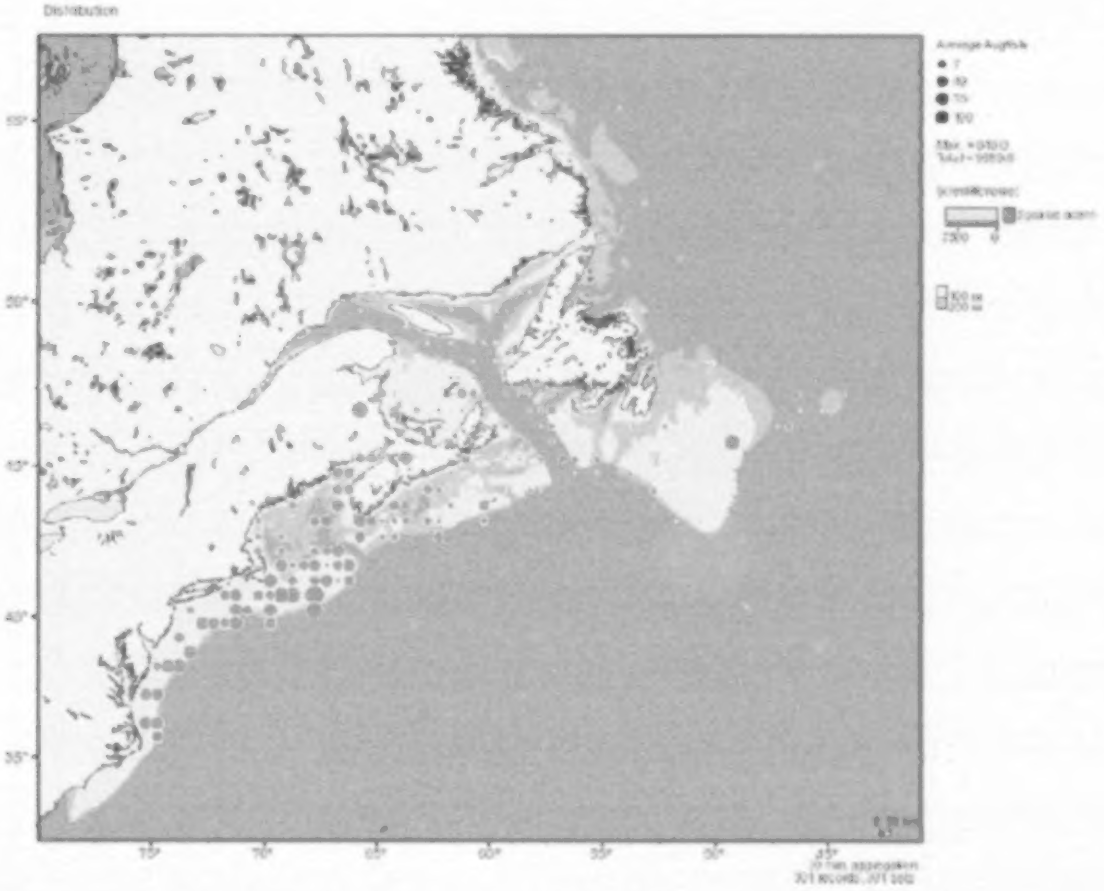

Distribution
55°
50°
45°
40°
35°
75°
70°
65°
60°
55°
50°
45°
100 m
200 m

Figure 1. Distribution of Spiny Dogfish along the eastern coast of North America, as recorded in East Coast of North America Strategic Assessment Project (ECNASAP).

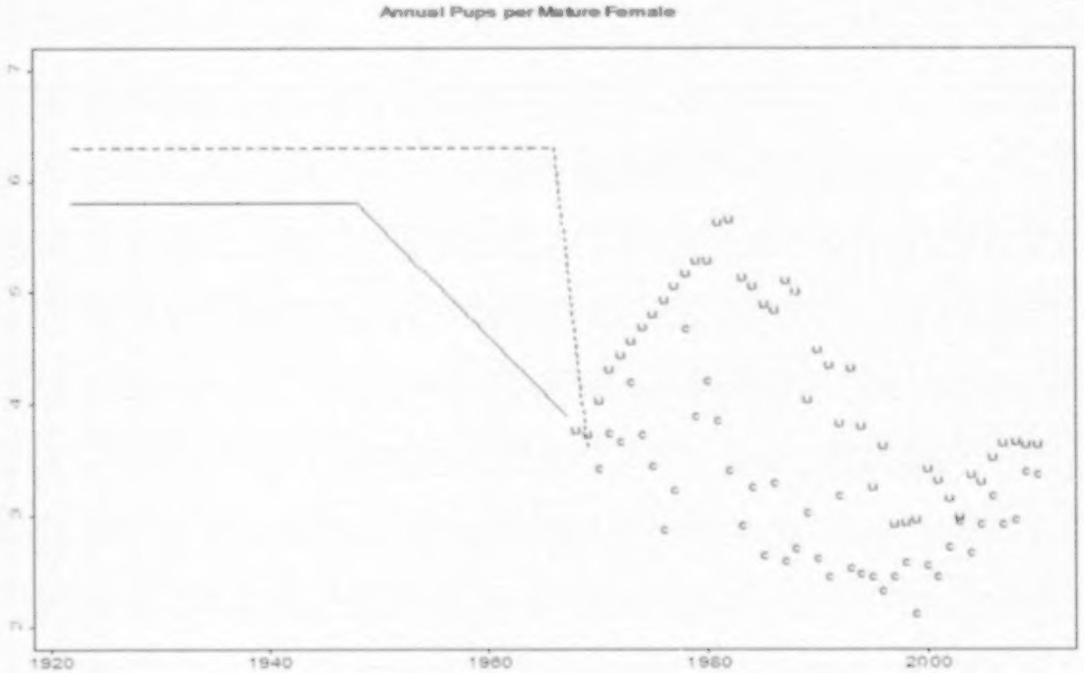
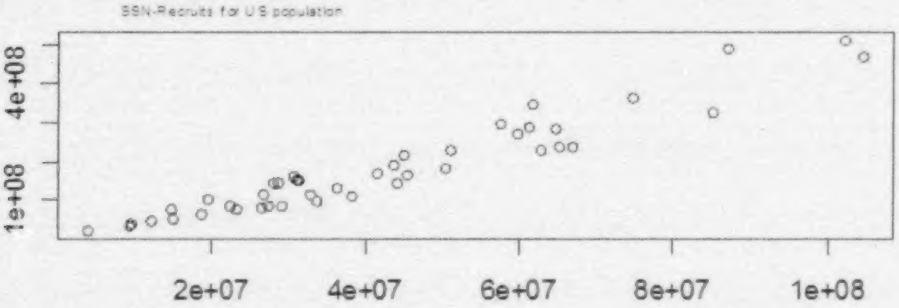


Figure 2. Pups per female determined by simulation of equilibrium conditions (straight line for the US, dashed line for Canada), observed length compositions of mature females (u = US, c = Canada), and interpolation between observed and simulated values using 0.1 increments.



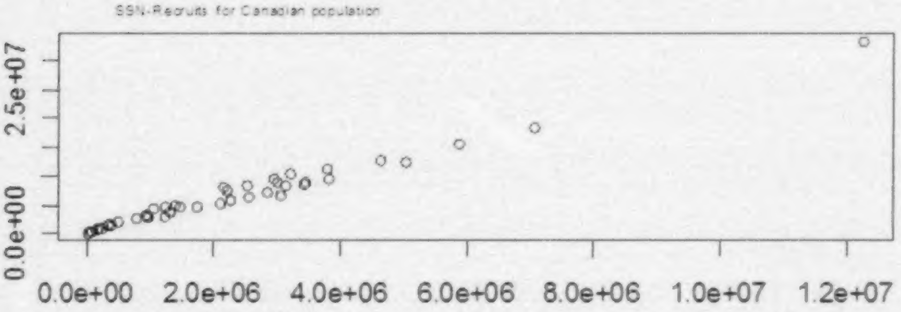


Figure 3. Deterministic stock-recruitment for surveyed time periods using observed abundance by number of mature females (SSN) and calculated mean pups per female.

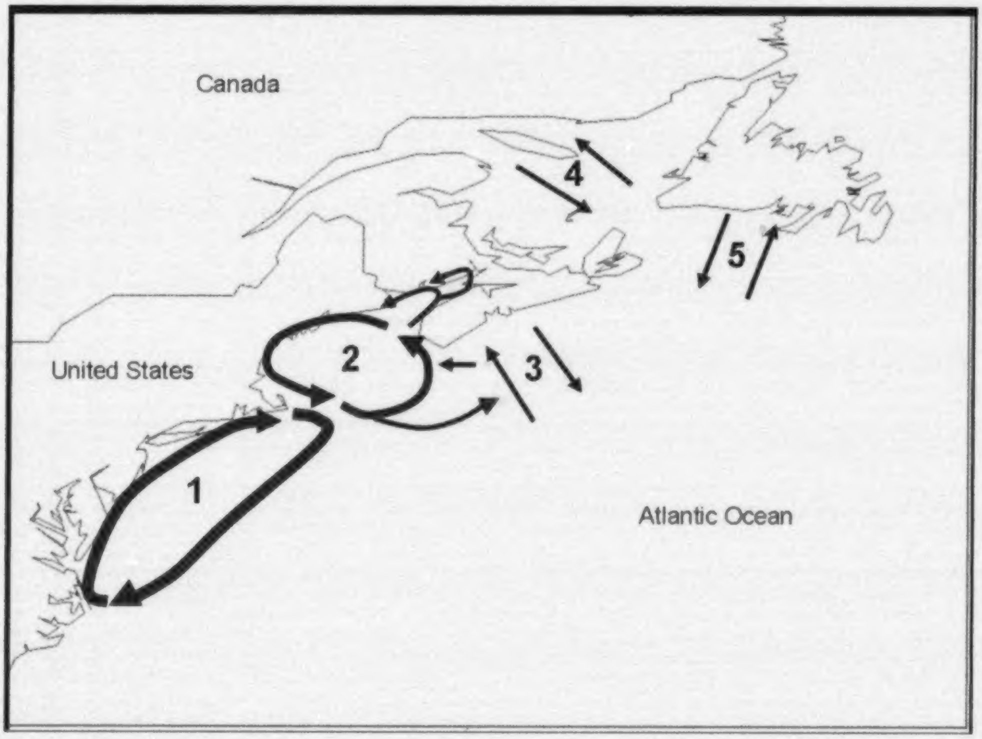

Canada
United States
Atlantic Ocean
1
2
3
4
5

Figure 4. Conceptual figure of dogfish movements.

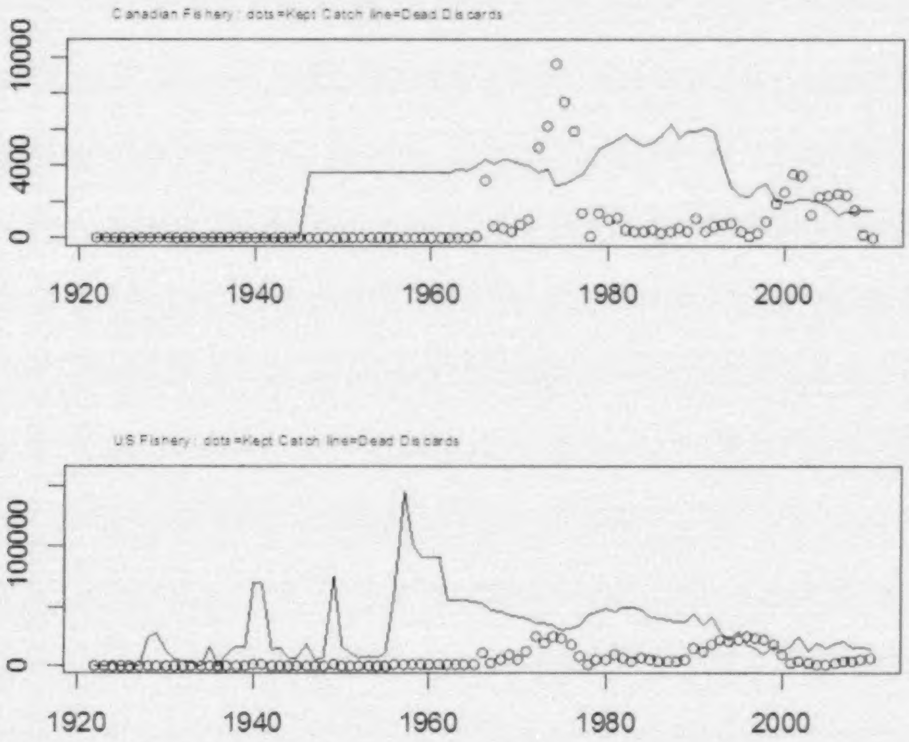


Figure 5. Total landings and dead discards (mt) of dogfish across all fisheries for Canada and the US.

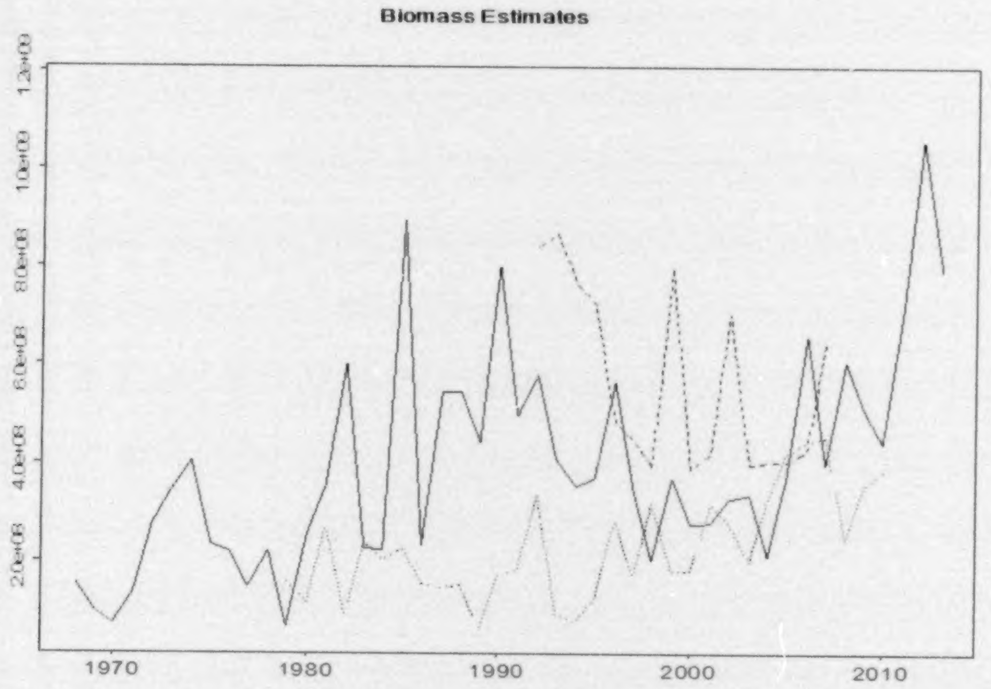


Figure 6. Biomass estimates (kgs) for the US Spring (solid line), Fall (dotted line), and Winter (dashed line) surveys through 2013, 2010 and 2007, respectively.

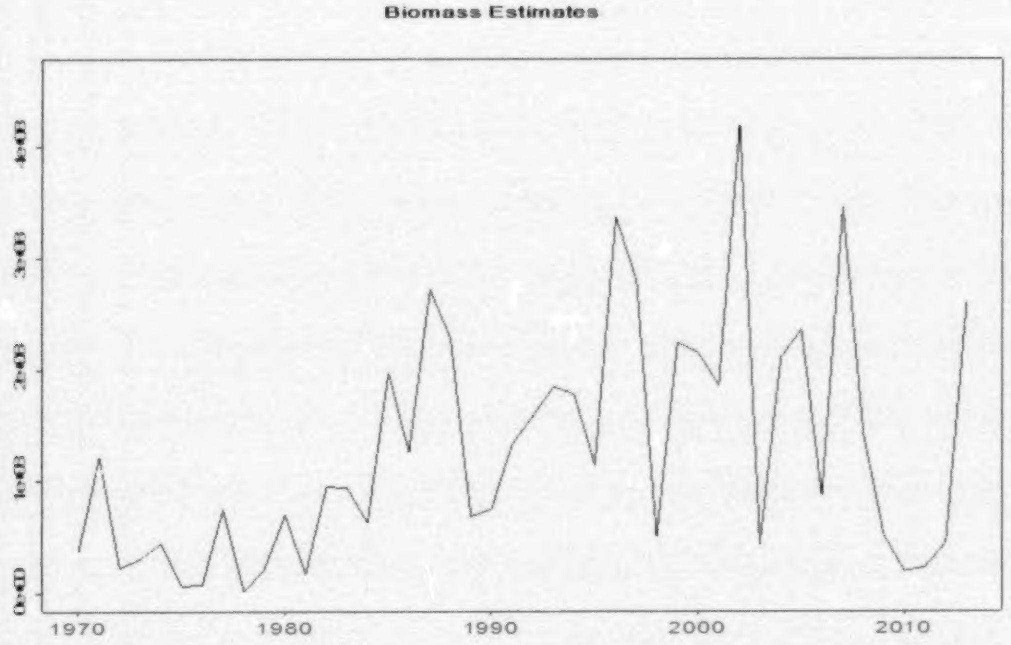


Figure 7. Biomass estimates (kgs) for the Canadian Summer RV survey through 2013.

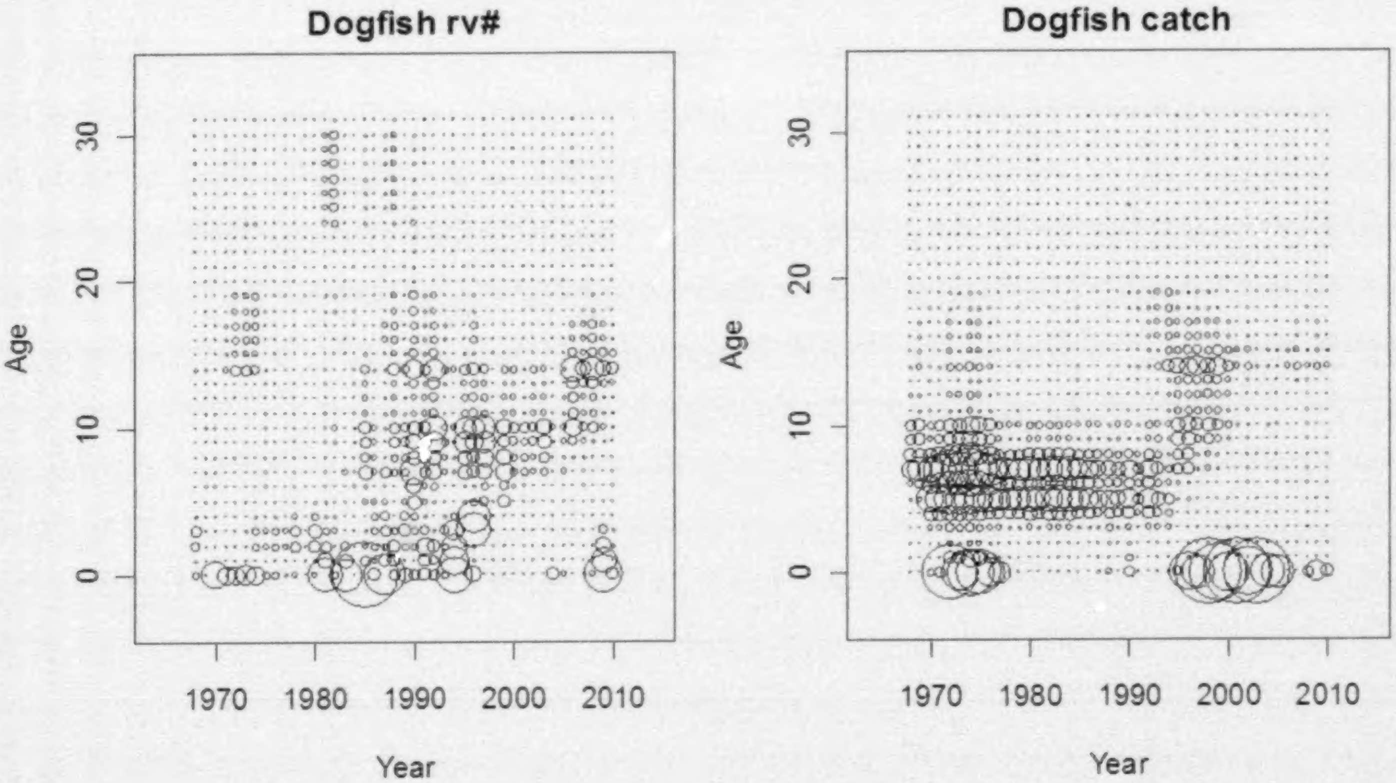


Figure 8. Numbers at age in the US Spring RV survey and the commercial catch (US and Canada combined).

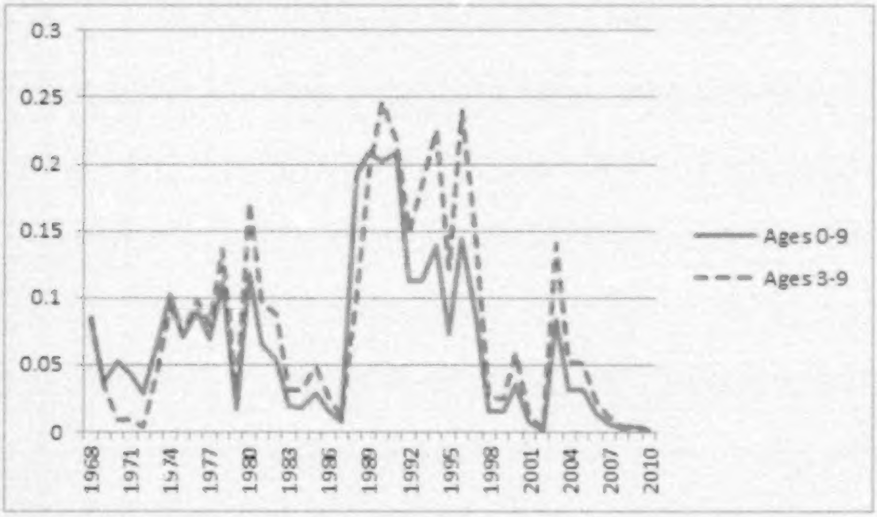


Figure 9. Mean estimated catchabilities of young dogfish from VPA modelling with and without ages that might be dominated by demersal pups.

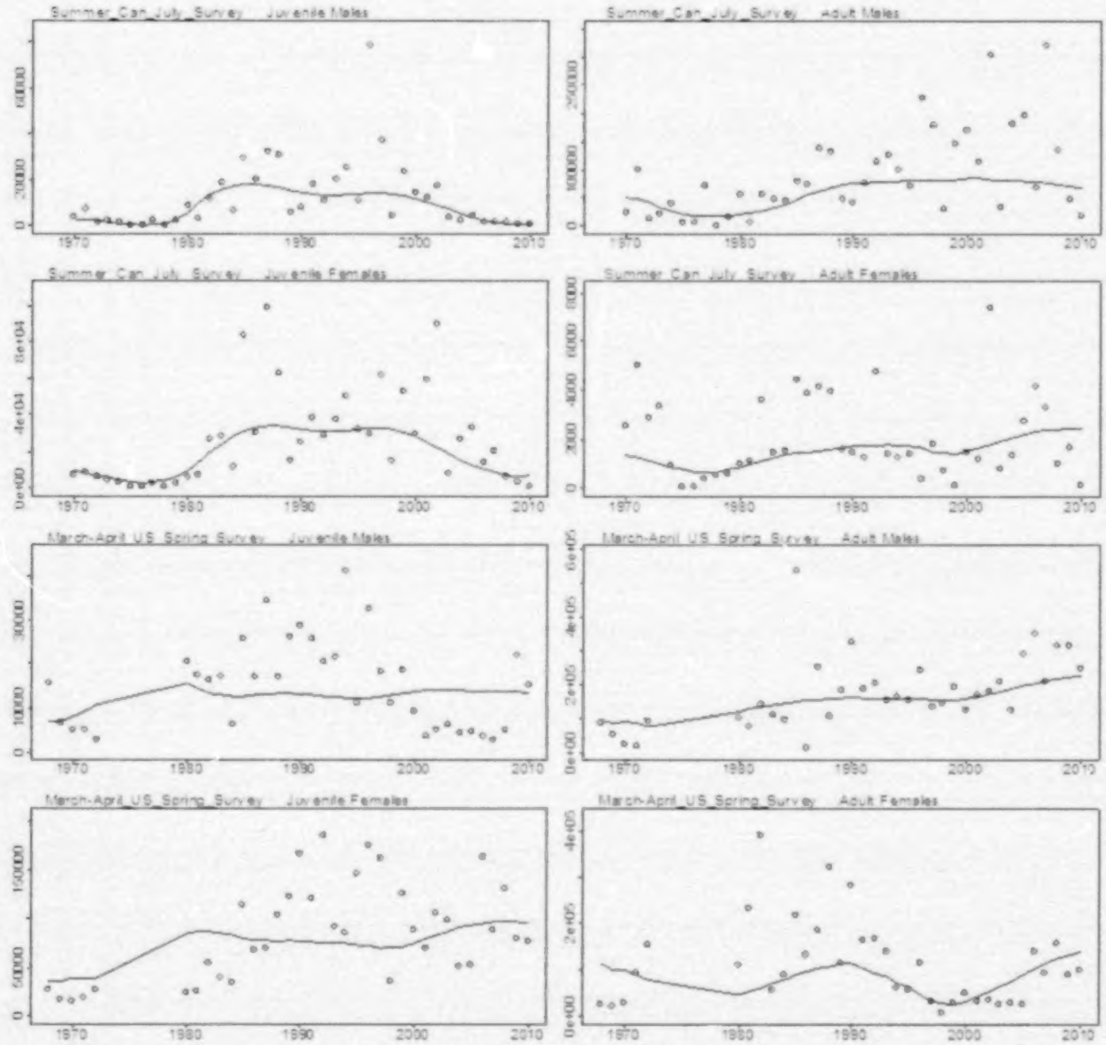


Figure 10. Fits to survey estimates of a length-based model developed and rejected during TRAC. Region 1 = Canada, 2 = US.

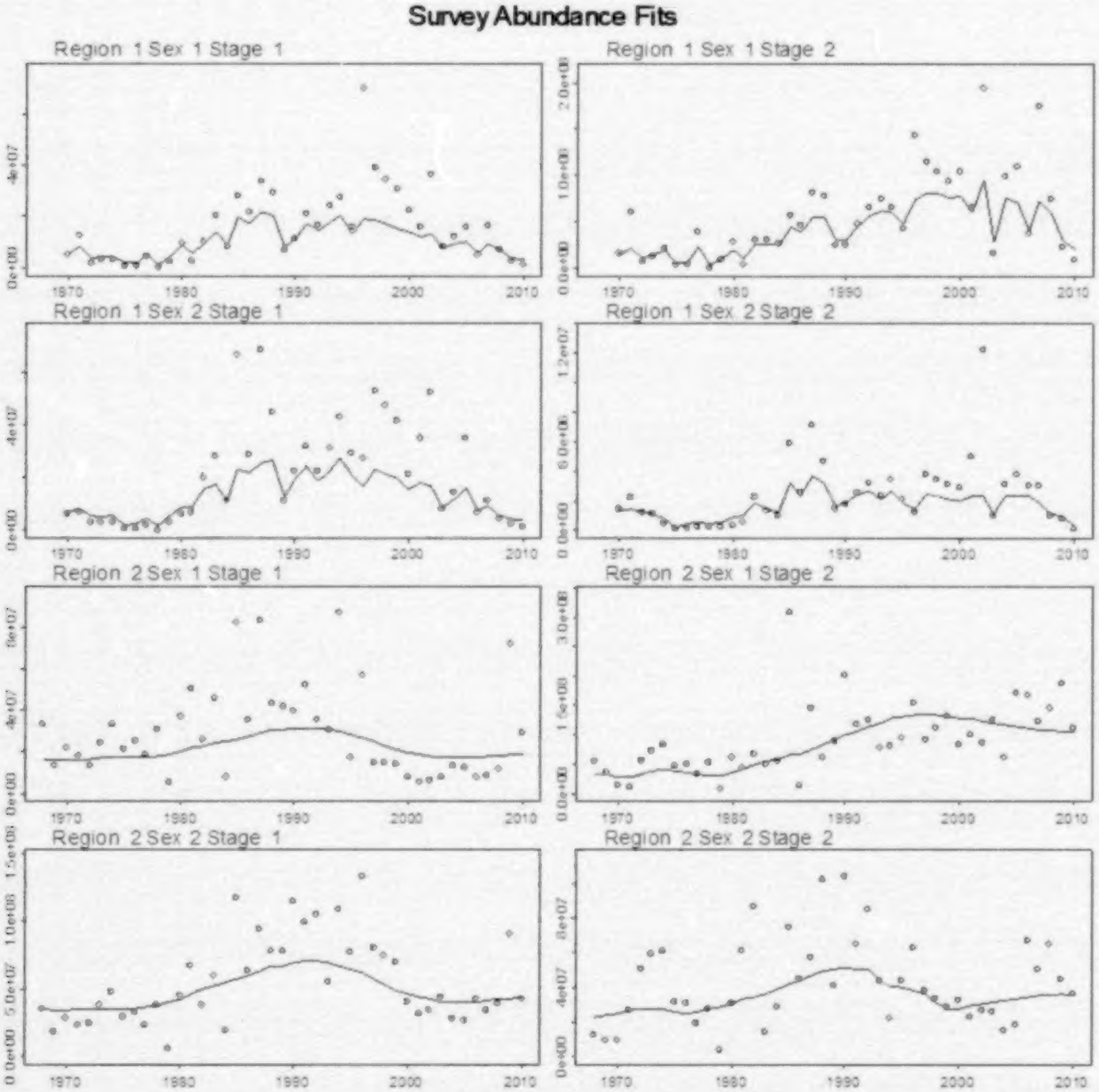


Figure 11. Stage-based model fits to survey estimates. Region 1 = Canada, 2 = US.

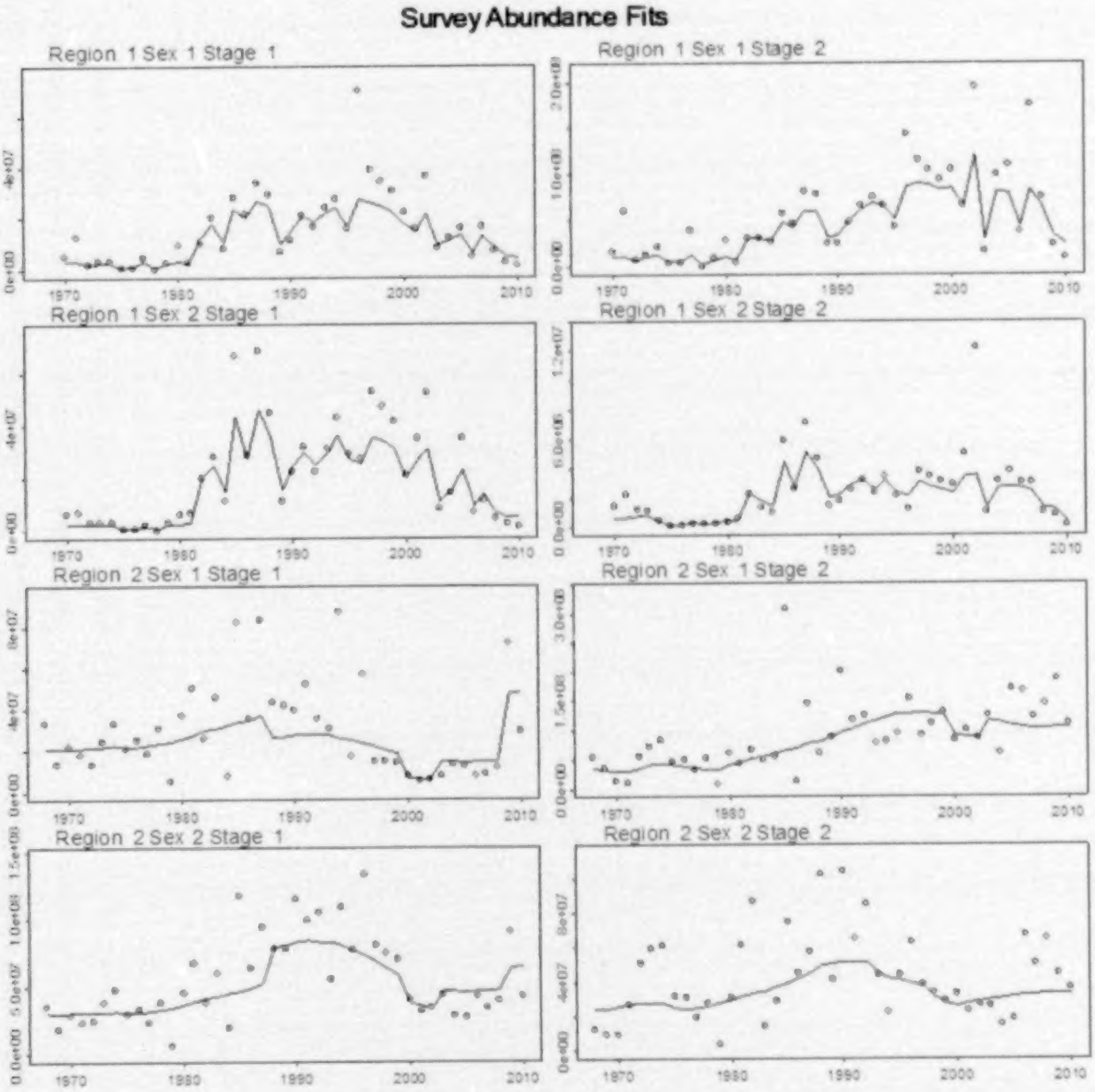


Figure 12. Stage-based model with Q regimes - fits to survey estimates. Region 1 = Canada, 2 = US.

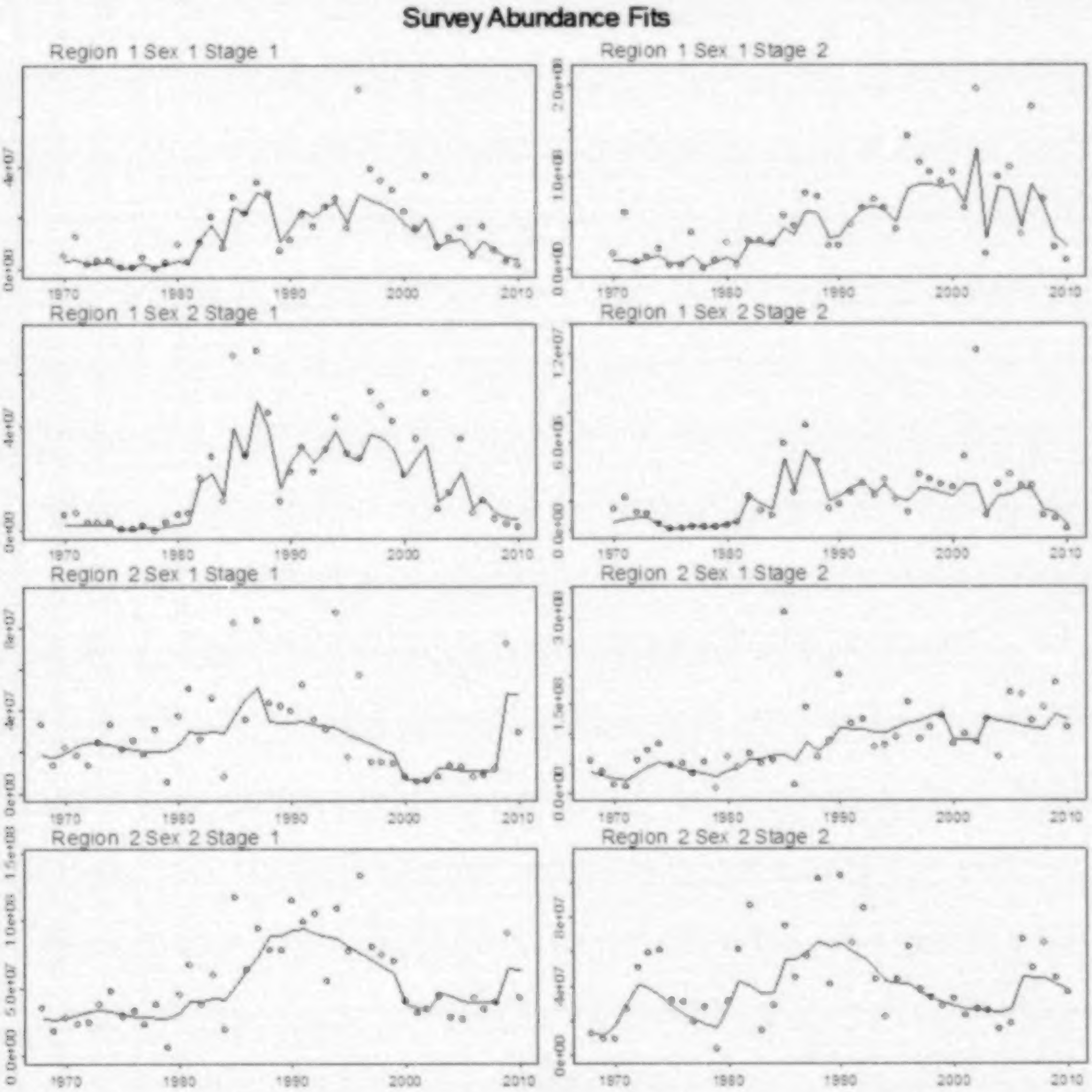


Figure 13. Base model. Fits to survey estimates of the stage-based model with annual deviates on maturation rates (theta) and pupping rates. Region 1 = Canada, 2 = US.

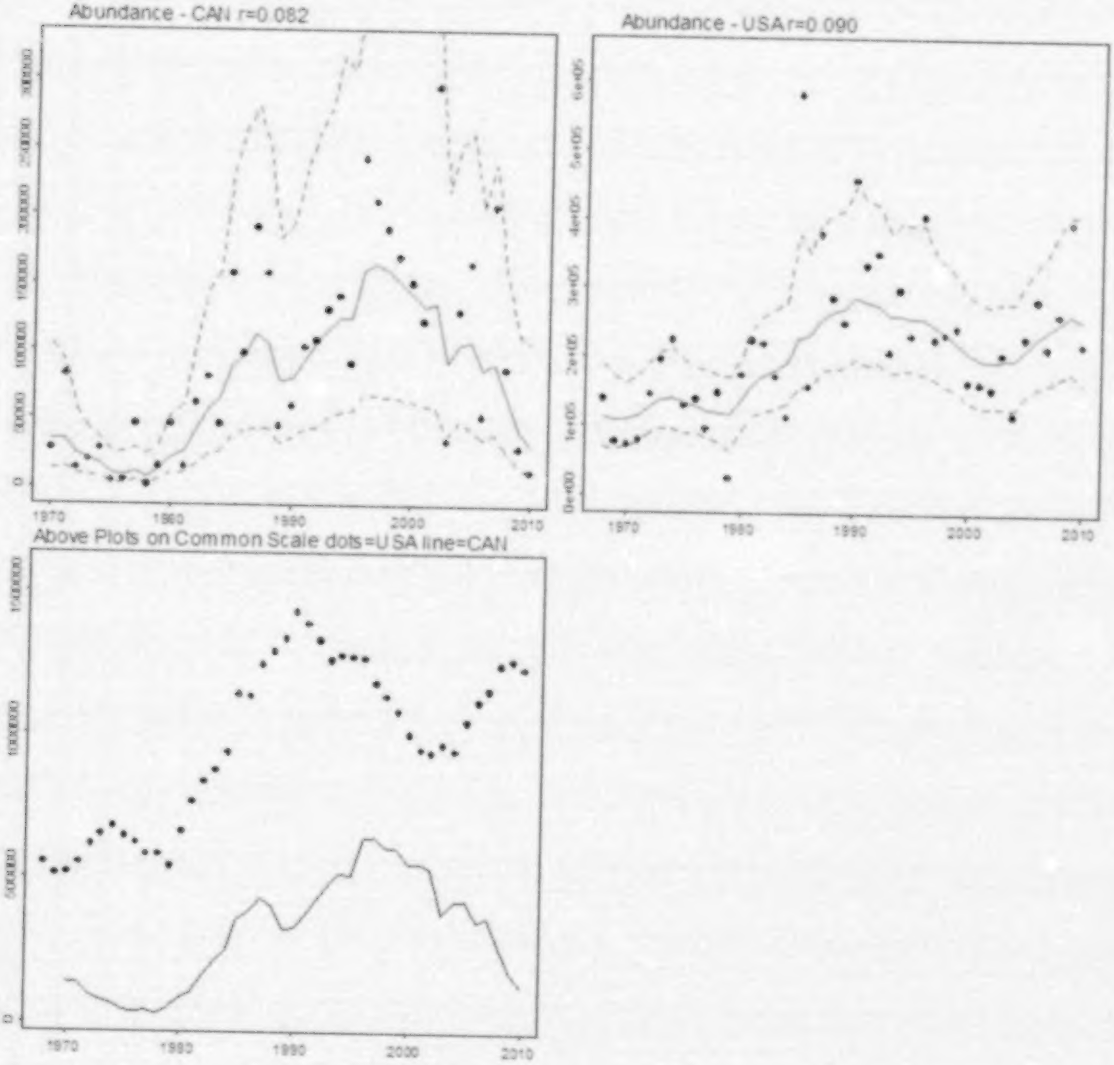


Figure 14. Top panels - Predicted (lines) and observed (dots) stock abundances from Canadian and US surplus production models ('000s of fish). The dashed lines are 95% confidence intervals. Bottom panel – Predicted stock abundances of Canadian (line) and US (dots) stock abundance on the same scale for comparison.

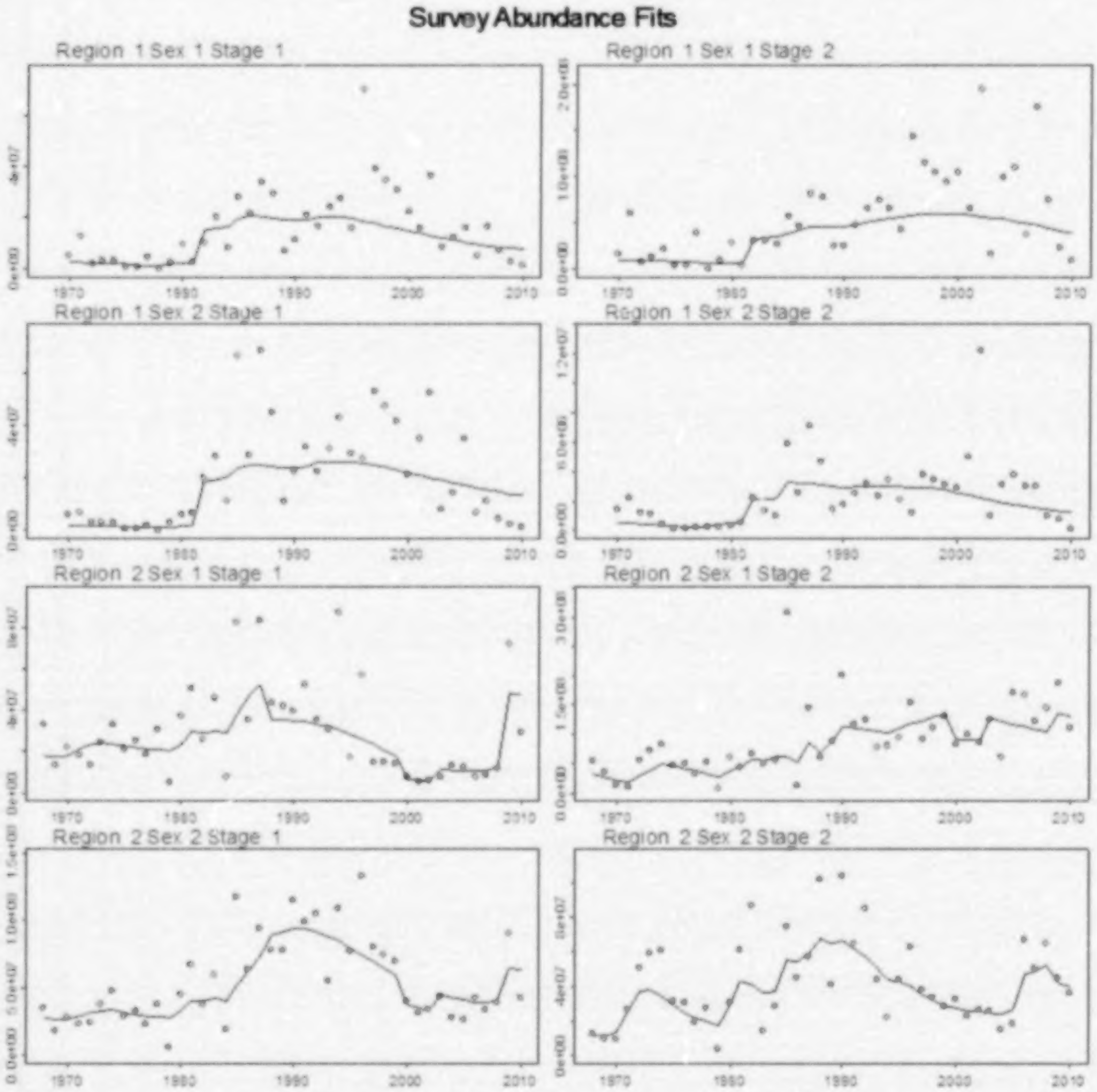


Figure 15. Stock abundance estimates from variant of base model in which migration was not permitted. Region 1 = Canada, 2 = US.

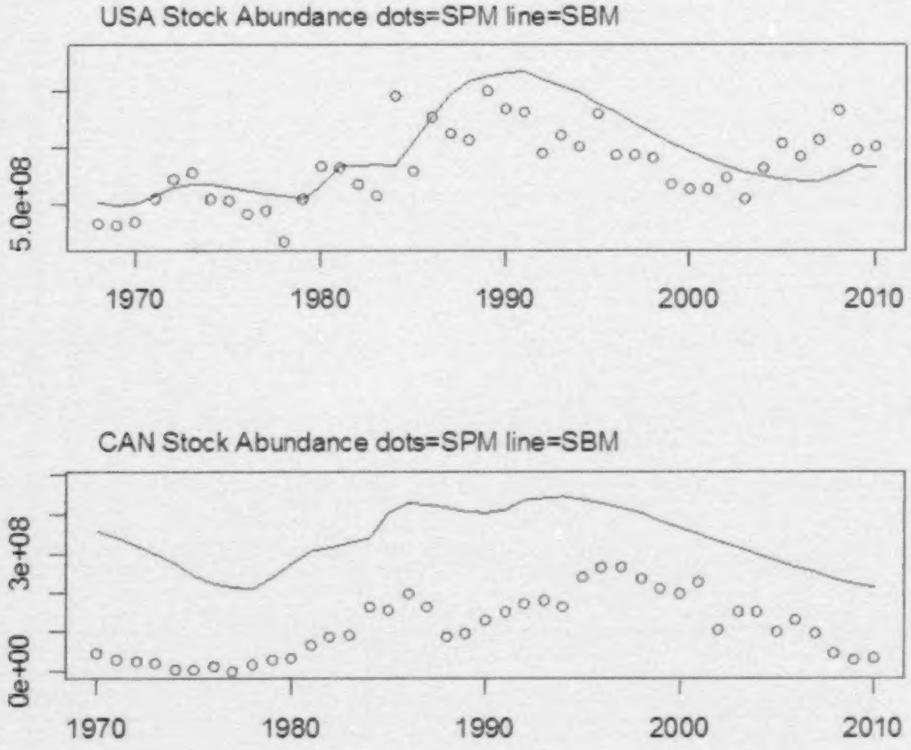


Figure 16. Stock abundance estimates from surplus production (SPM) and stage-based (SBM) models.

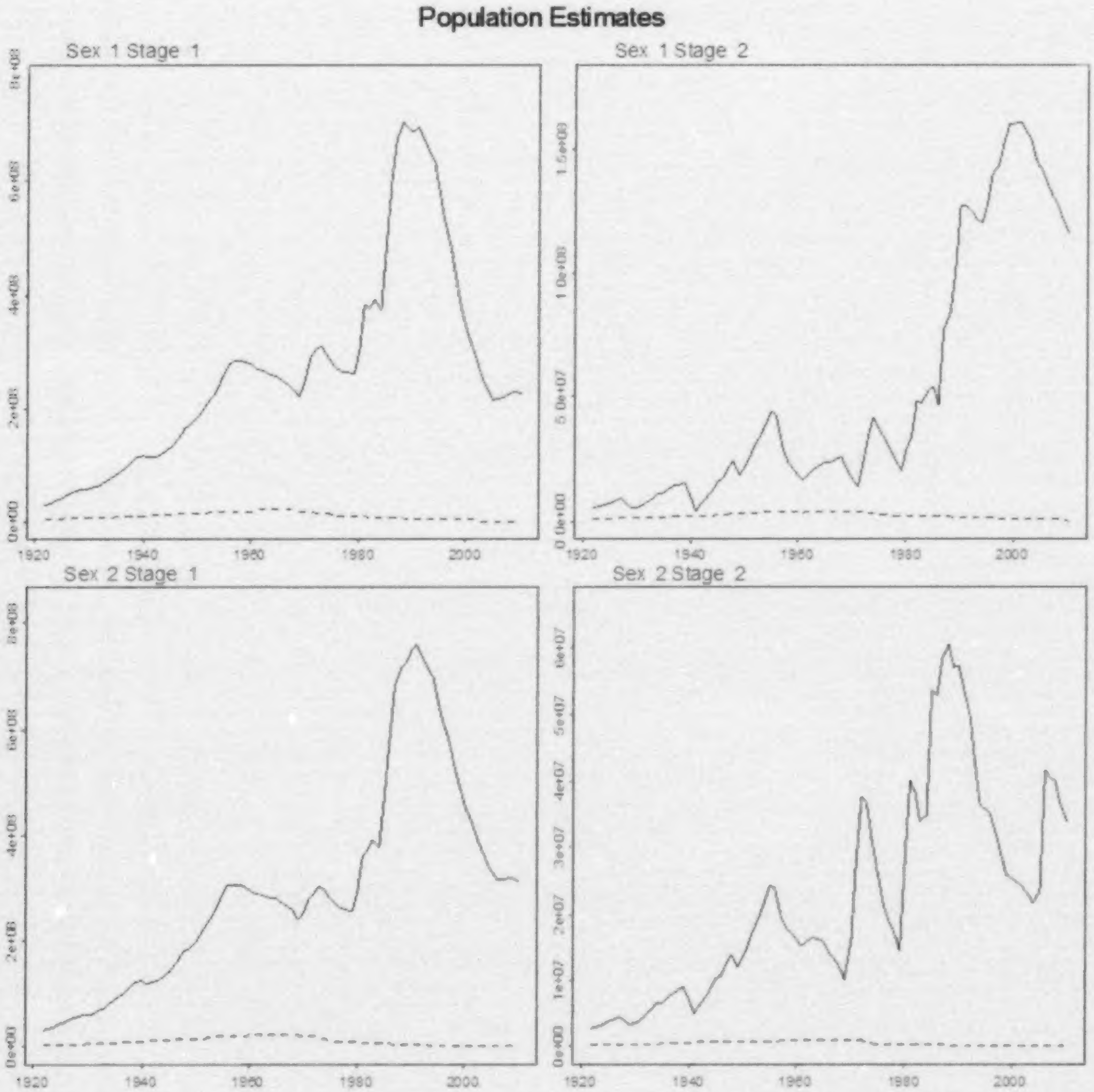


Figure 17. Abundances of population components for the US (line) and Canadian (dashed line) regions predicted by the stage-based model.

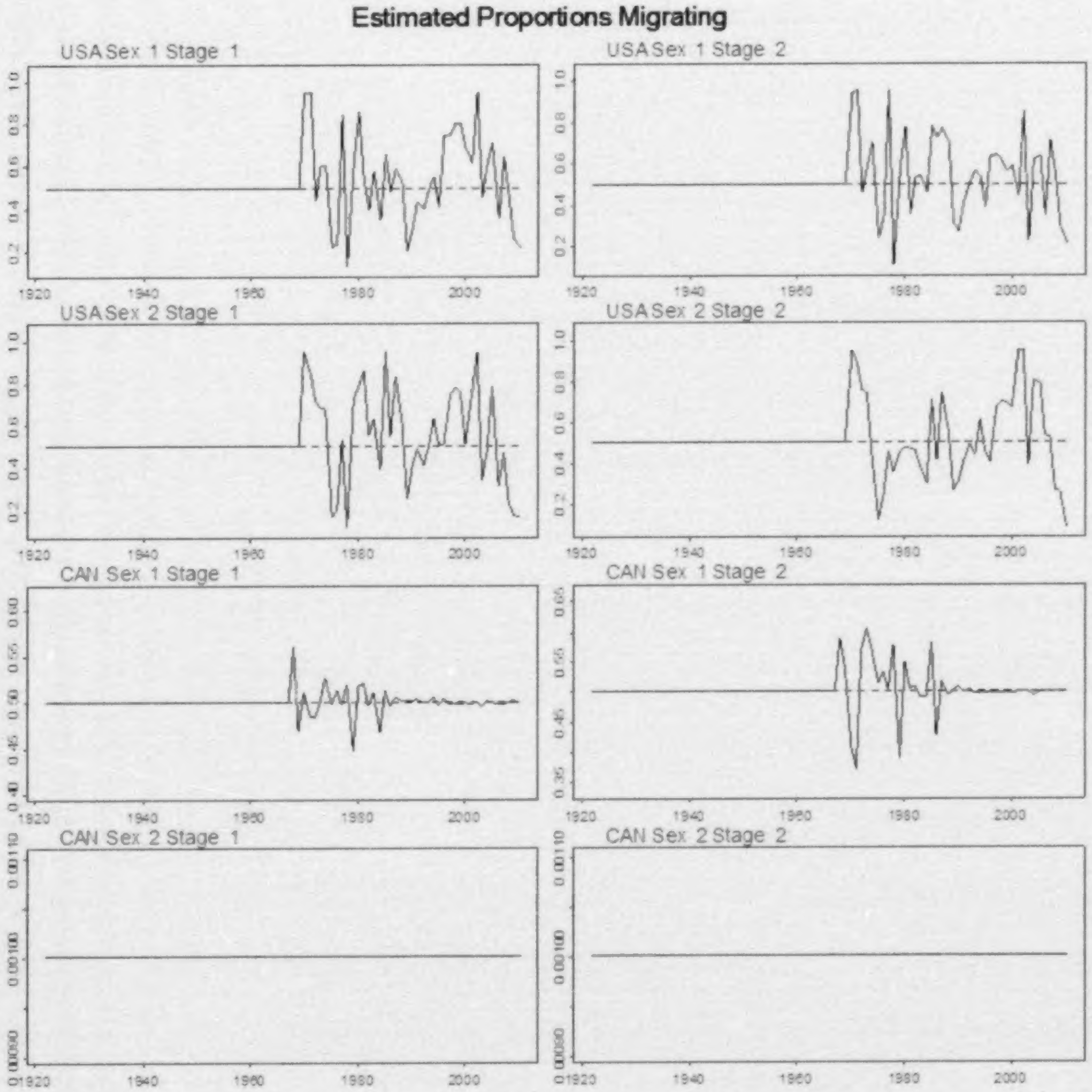


Figure 18. Annual estimates of proportions of population components migrating from US to Canadian waters in summer (US) and from Canadian to US waters in winter (CAN).

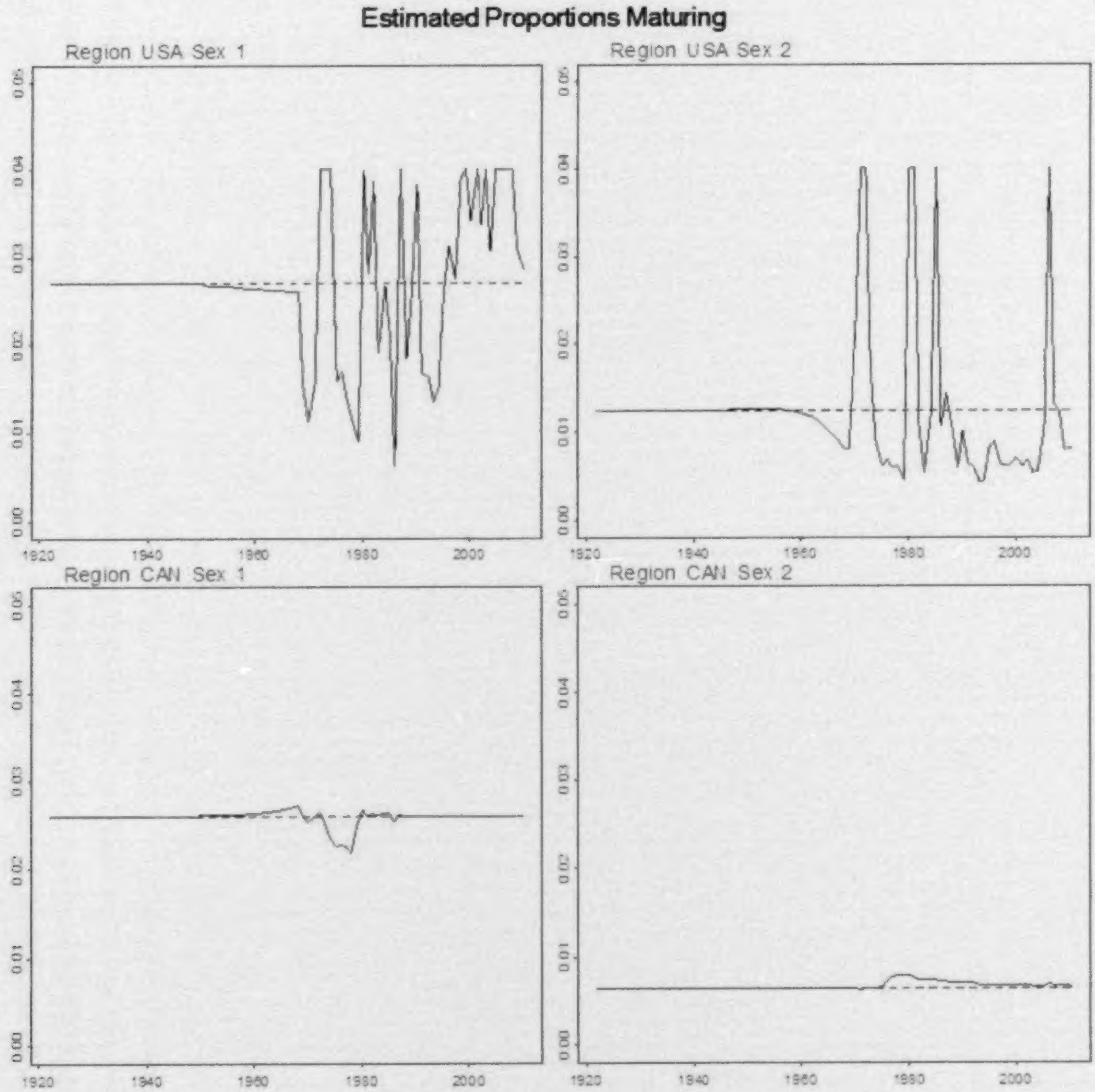


Figure 19. Annual estimates of proportions maturing (theta). The dashed lines depict the deterministic mean constants. Prdeicted estimates bound between 0 and 0.04.

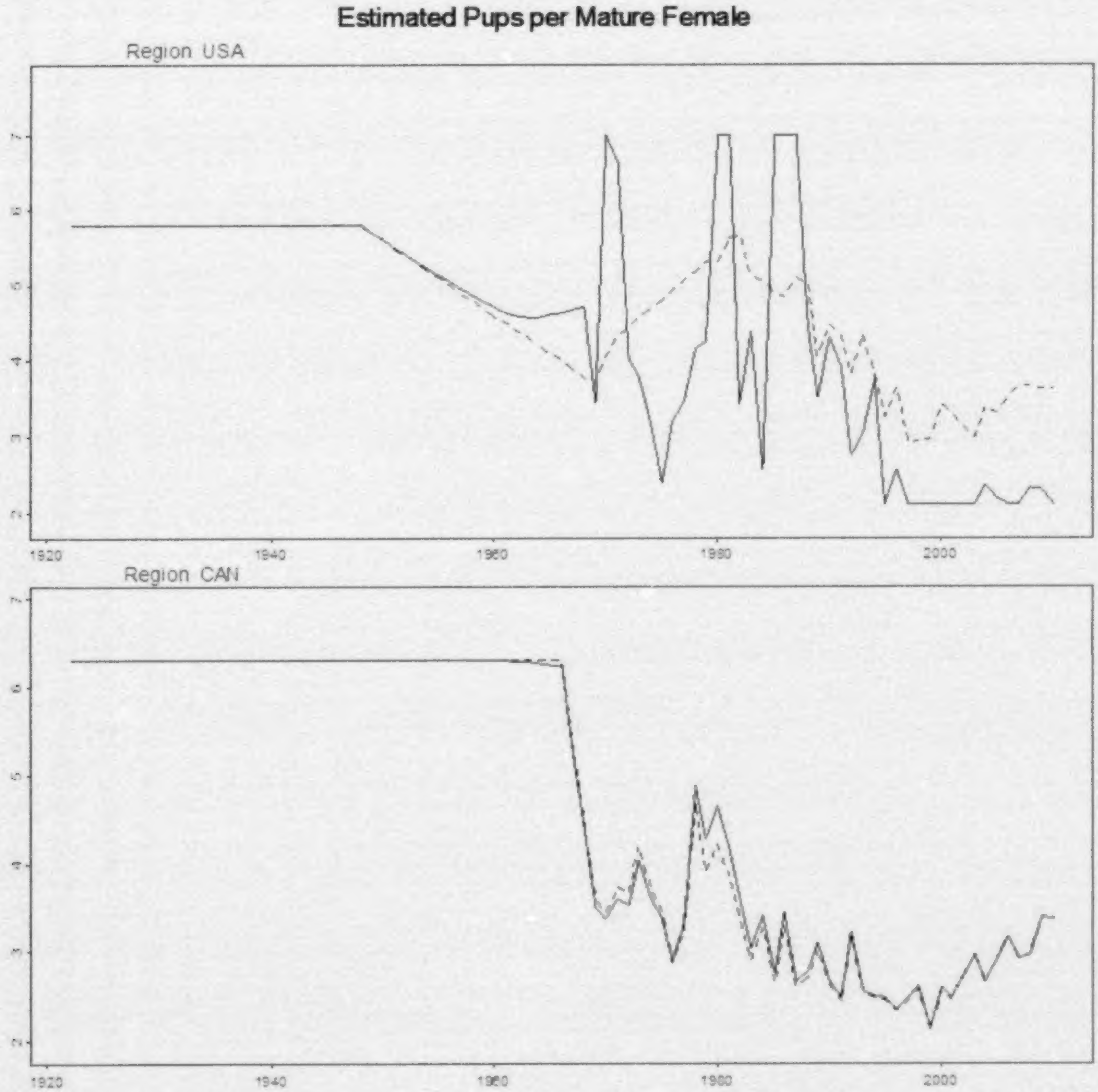


Figure 20. Annual estimates of pups per mature female. Dashed lines show deterministic mean constants for the earliest years (flat lines), interpolation ramps (diagonal straight lines), and calculated values based on observed size compositions for survey years. Predicted estimates are bounded between 2.1 and 7.0.

Population (Migration) Model

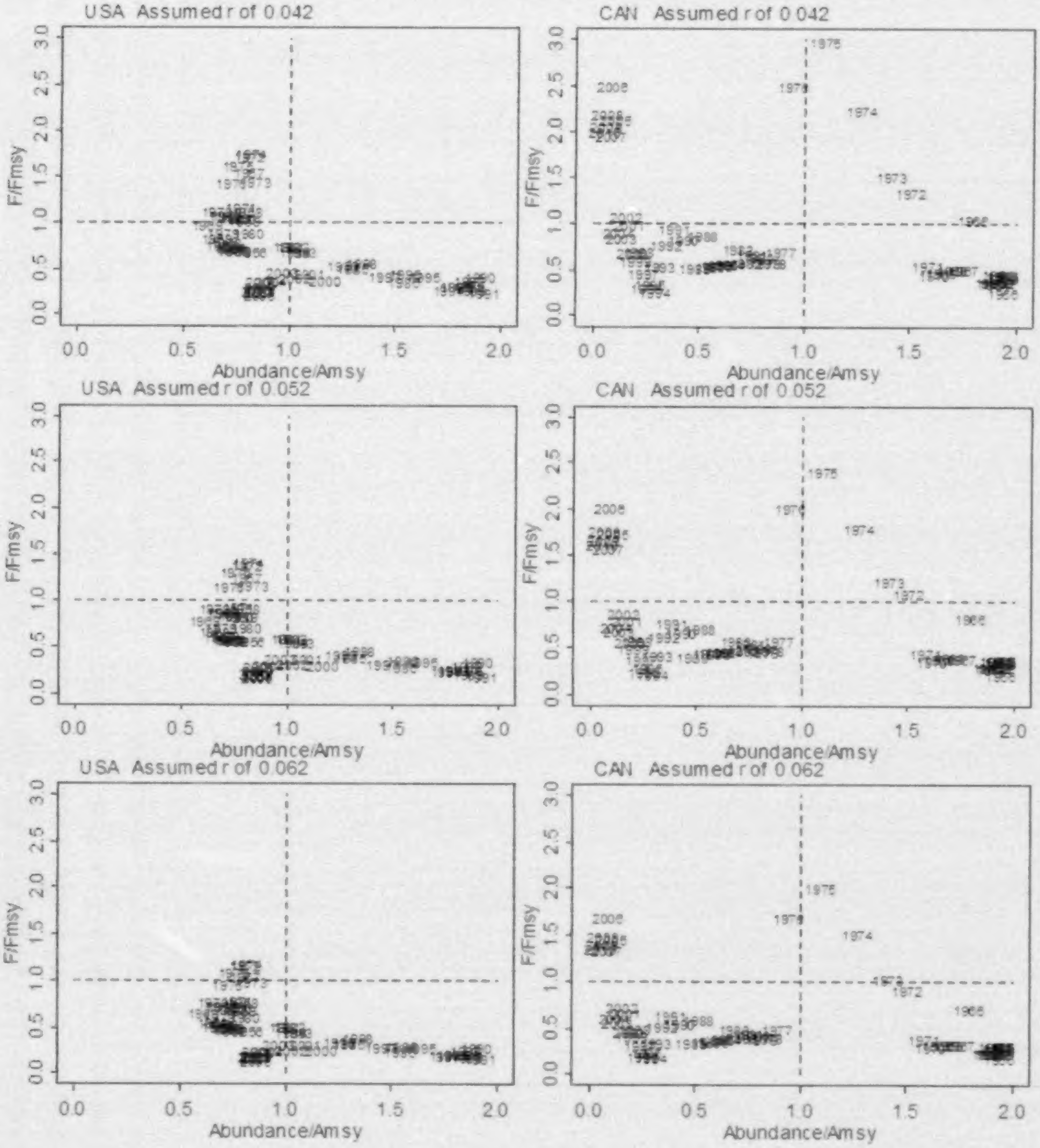
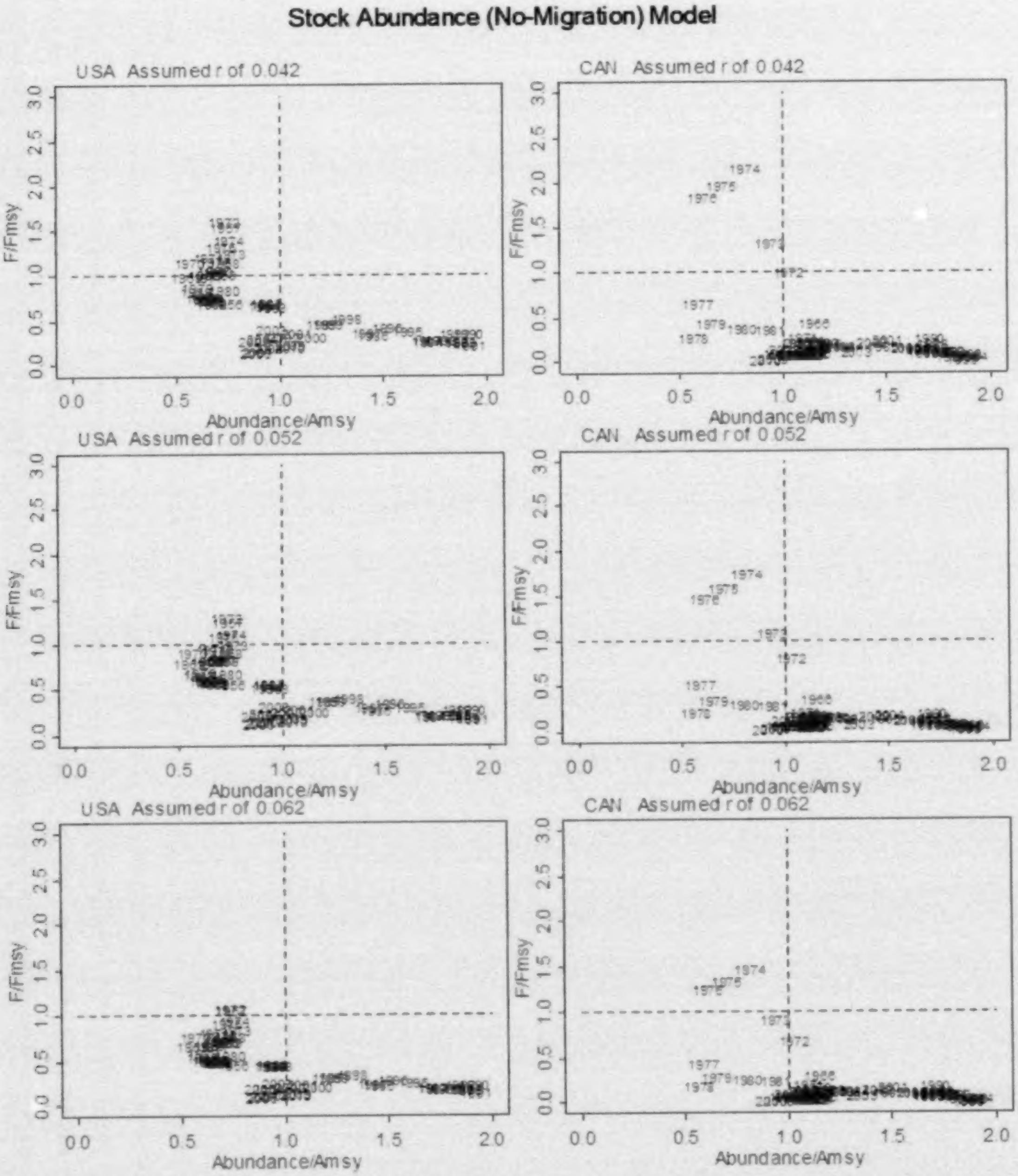


Figure 21. Phase plots relating abundance (A) to exploitation (F) in the context of Maximum Sustainable Yield (MSY), F_{MSY} and A_{MSY}, for the base model under three assumptions of intrinsic population growth rates (r).



Stock Abundance (No-Migration) Model

USA Assumed r of 0.042

CAN Assumed r of 0.042

USA Assumed r of 0.052

CAN Assumed r of 0.052

USA Assumed r of 0.062

CAN Assumed r of 0.062

Figure 22. Phase plots relating stock abundance to exploitation in the context of Maximum Sustainable Yield (MSY) for the no-migration model under three assumptions of intrinsic population growth rates (r).

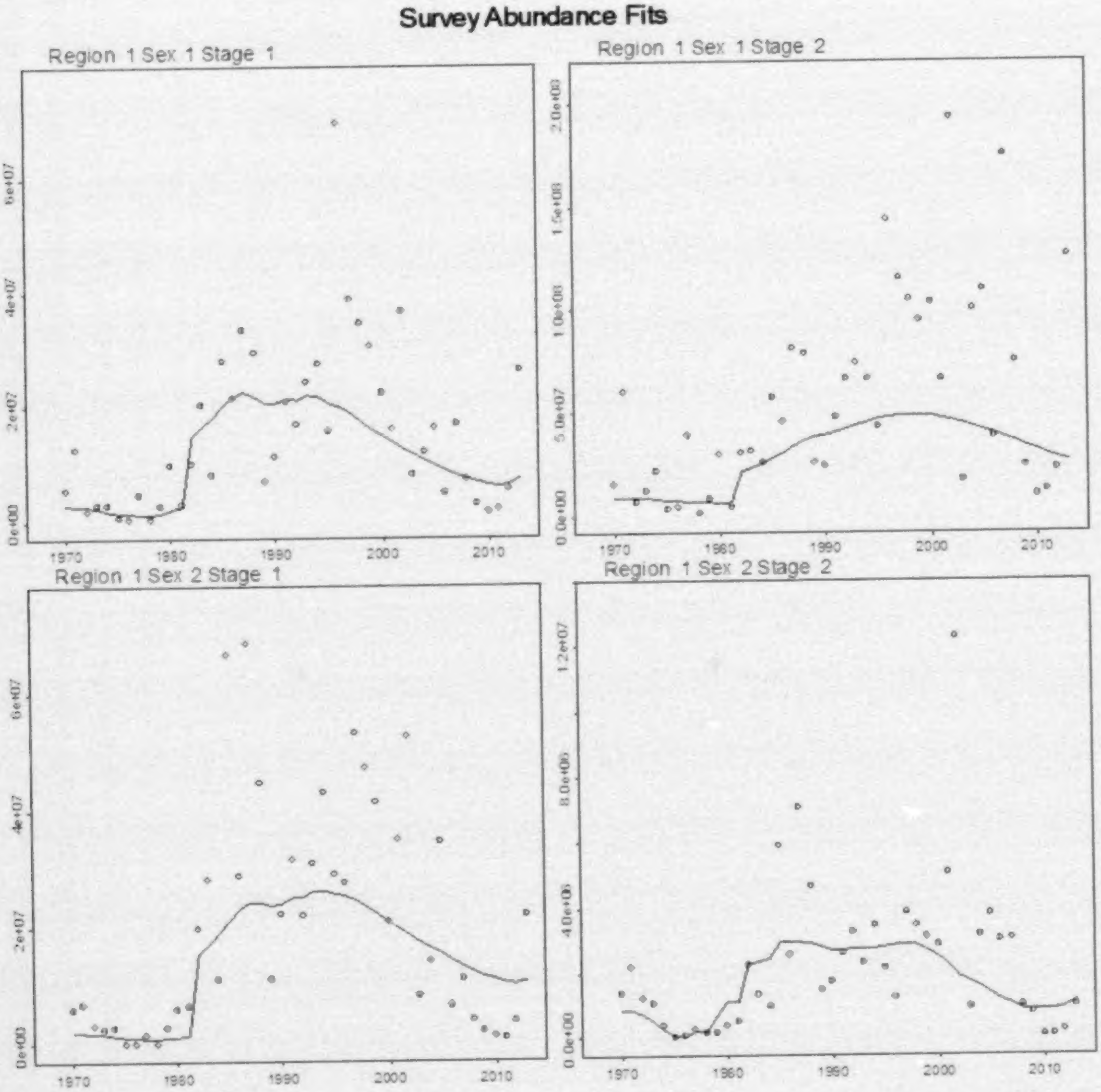


Figure 23. Update model fits to Canadian Summer RV survey estimates.

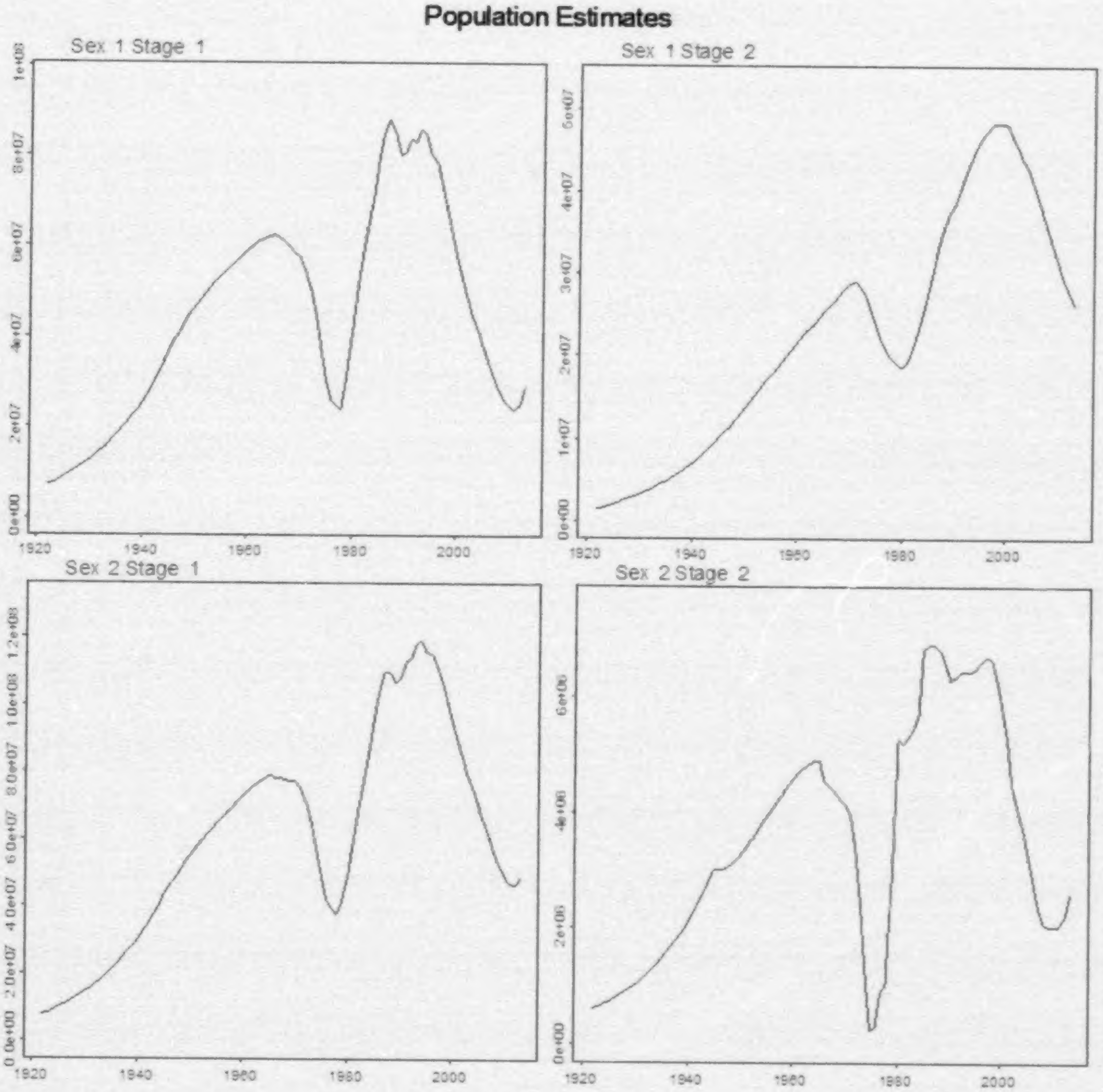


Figure 24. Canadian stock abundance by component as predicted by the update model.

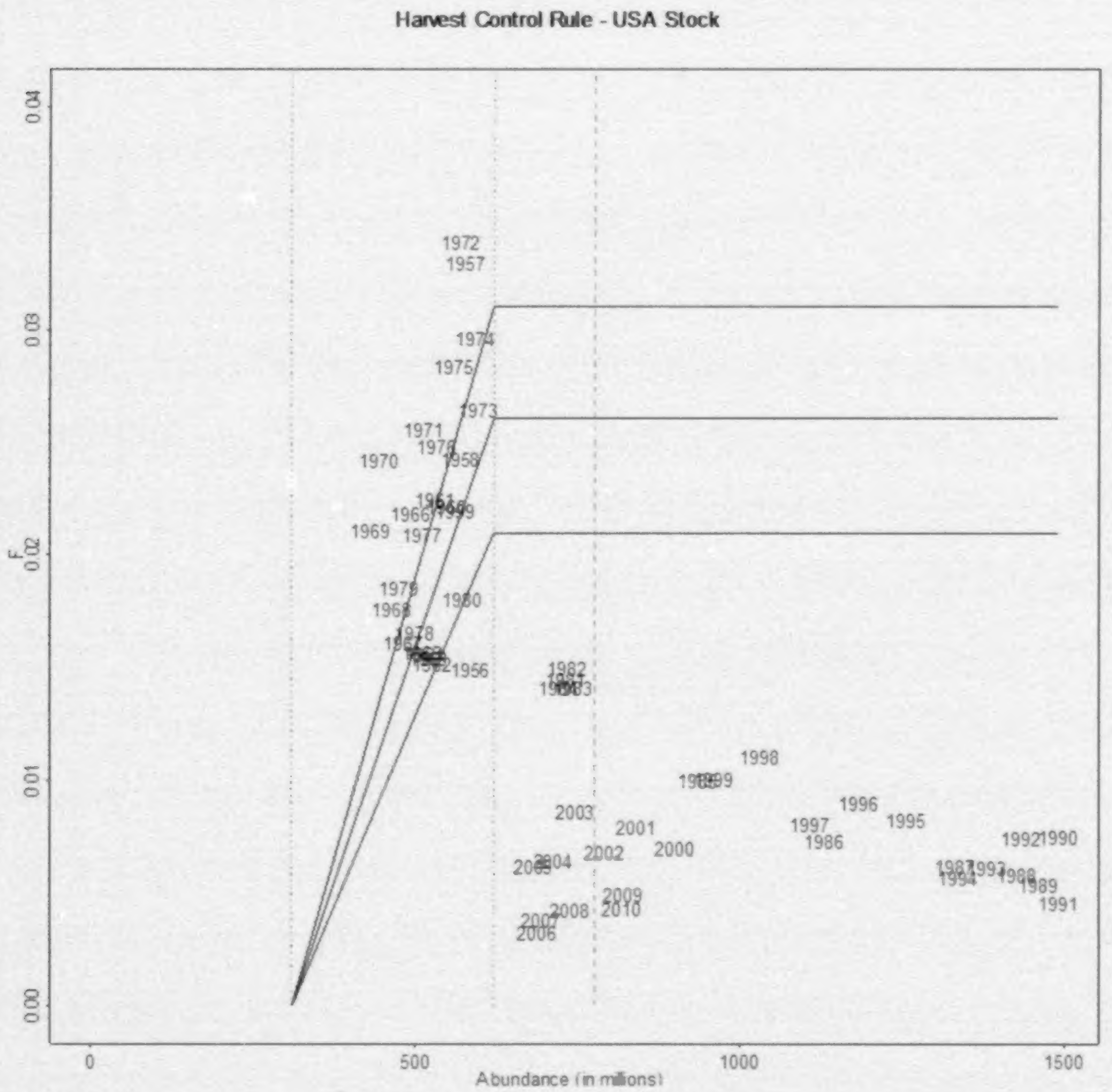


Figure 25. Harvest Control Rule (HCR) plot for the US stock from the no-migration model. DFO defaults define the lower reference point (LRP) as 40% of A_{MSY} (dotted red line) and the upper reference point (URP) as 80% of A_{MSY} (dotted green line). A_{MSY} is depicted as a notional Removal (Target) Reference (RR) line (dashed green). Scenarios for three assumed population growth rates are shown (bottom to top: r= .042, .052, .062).

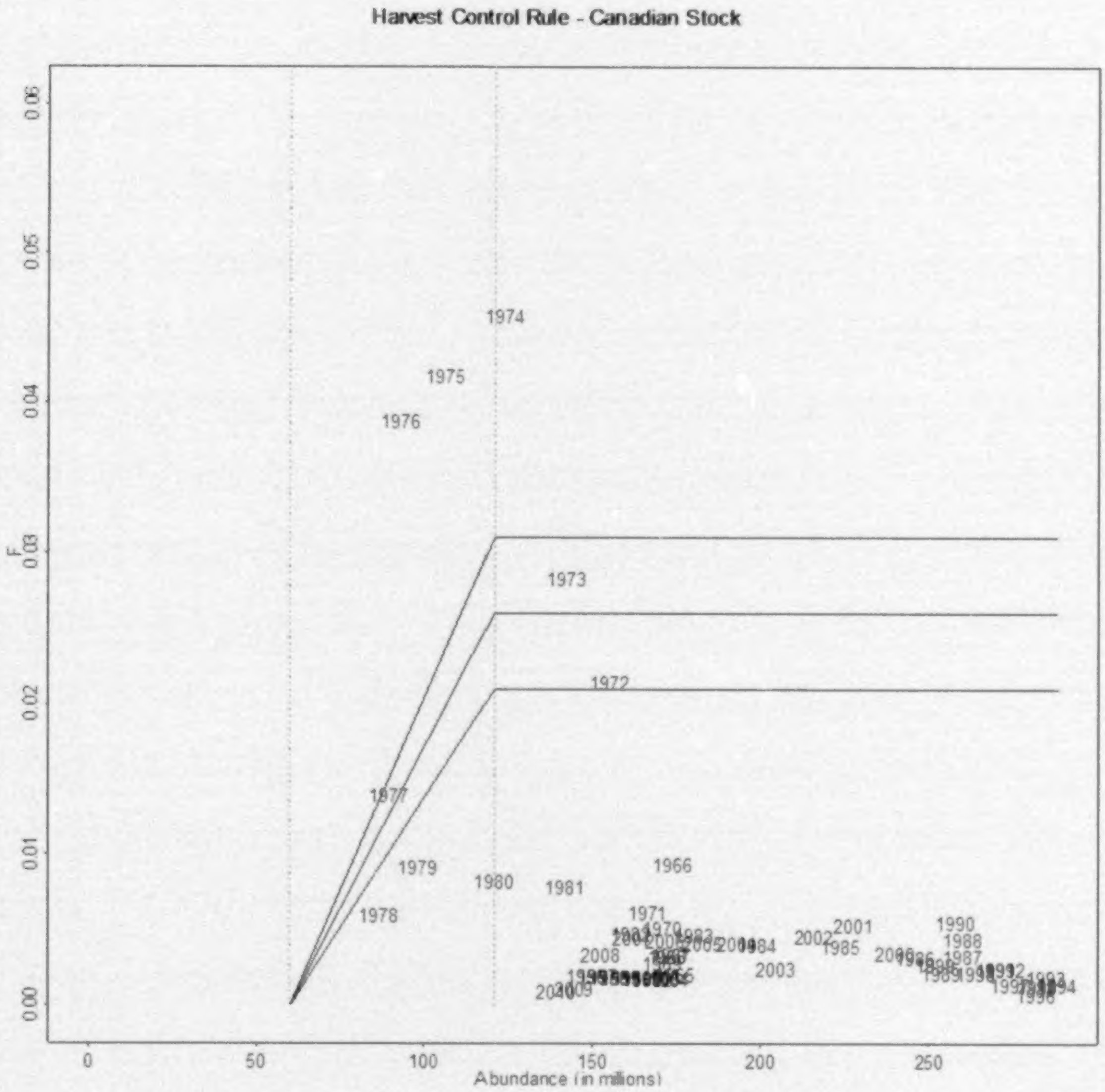
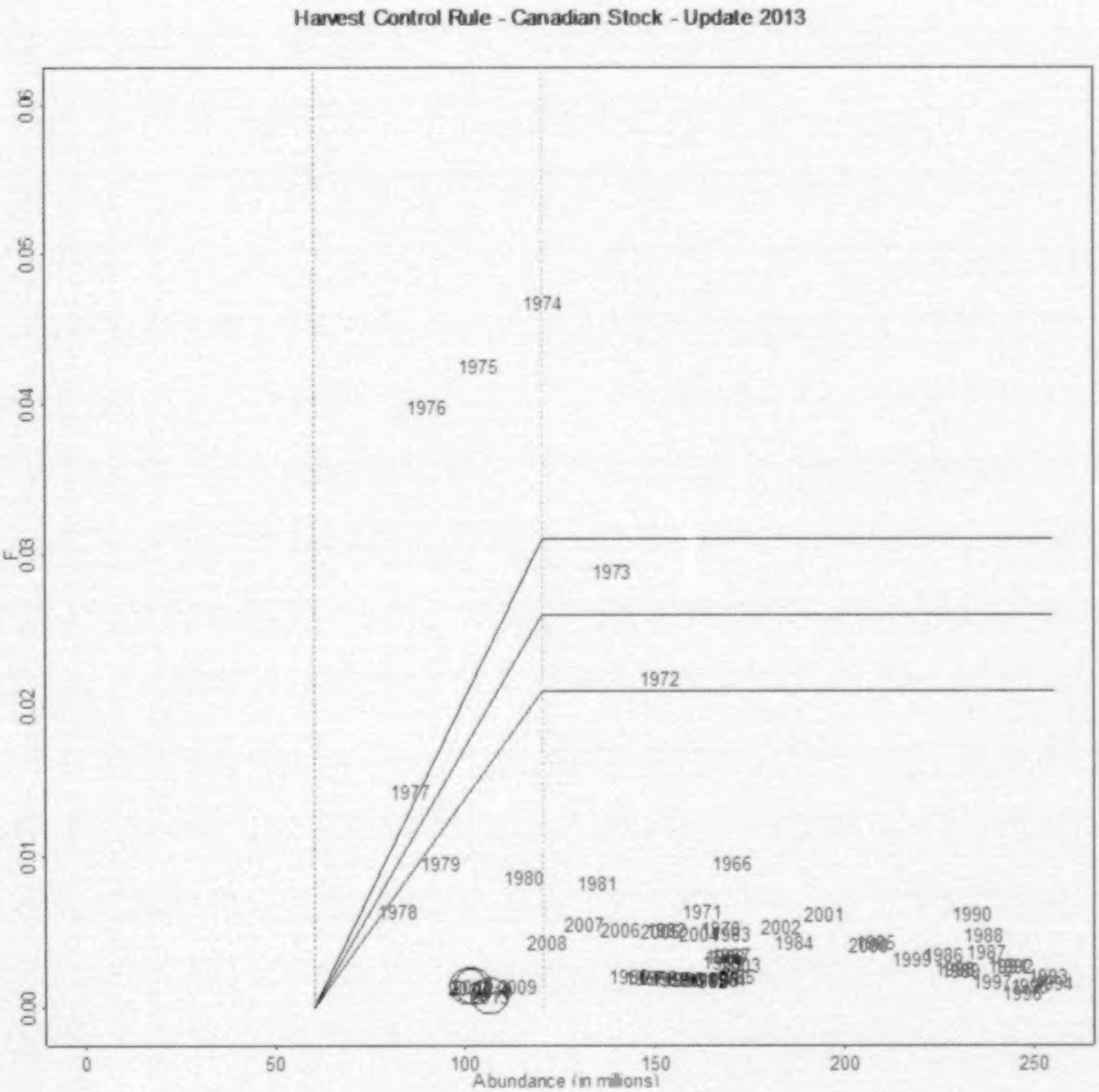


Figure 26. Harvest Control Rule (HCR) plot for the Canadian stock from the no-migration model.DFO defaults define the lower reference point (LRP) as 40% of A_{MSY} (dotted red line) and the upper reference point (URP) as 80% of A_{MSY} (dotted green line). A_{MSY} is depicted as a notional Removal (Target) Reference (RR) line (dashed green). Scenarios for three assumed population growth rates are shown (bottom to top: r= .042, .052, .062).



Harvest Control Rule - Canadian Stock - Update 2013

Figure 27. Harvest Control Rule (HCR) plot for the Canadian stock from the no-migration update model (includes 2011-2013). DFO defaults define the lower reference point (LRP) as 40% of A_{MSY} (dotted red line) and the upper reference point (URP) as 80% of A_{MSY} (dotted green line). A_{MSY} is depicted as a notional Removal (Target) Reference (RR) line (dashed green). Scenarios for three assumed population growth rates are shown (bottom to top: r= .042, .052, .062).

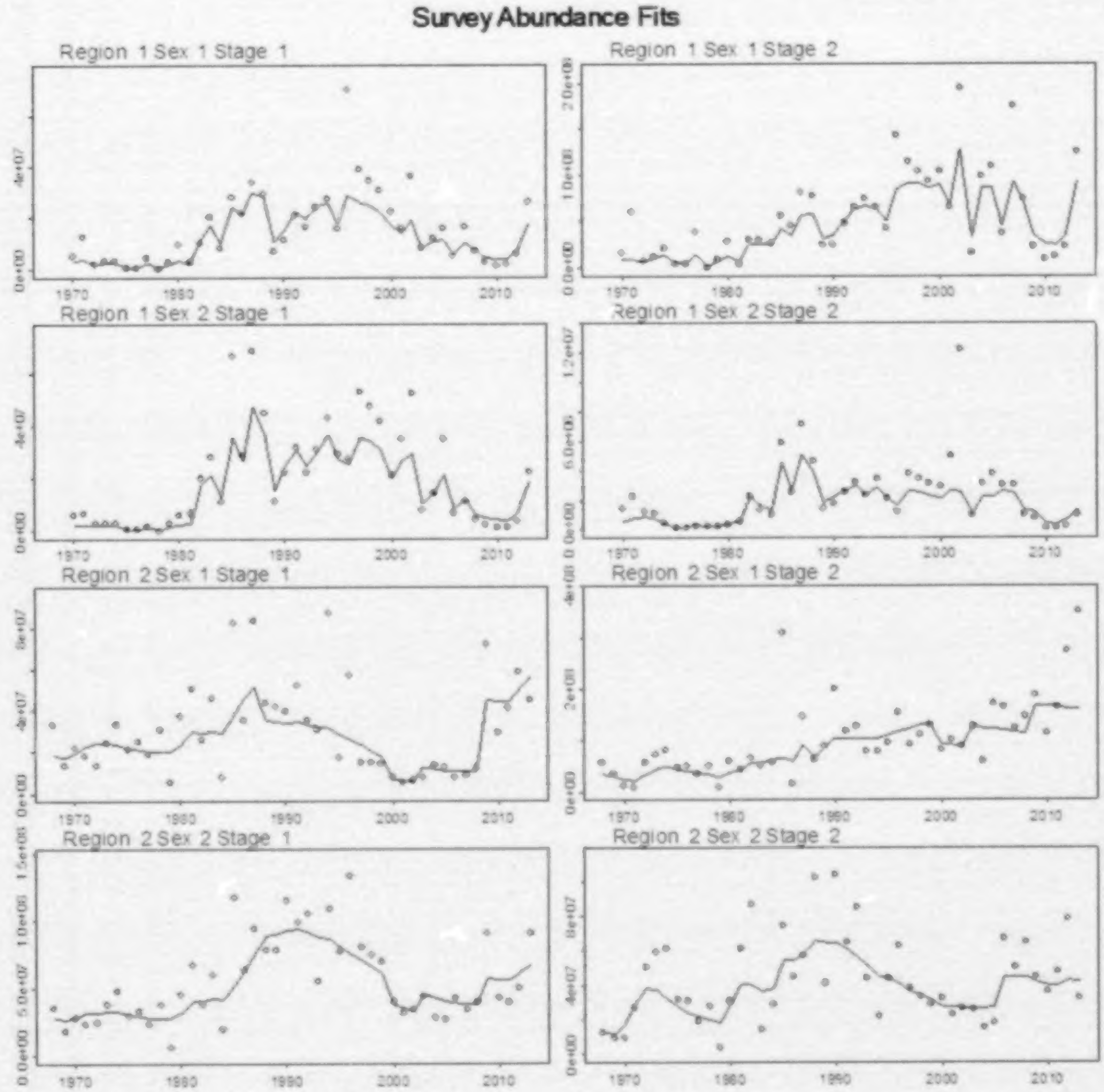


Figure 28. Fits to survey estimates of the stage-based population model updated through 2013. Region 1 = Canada, 2 = US.

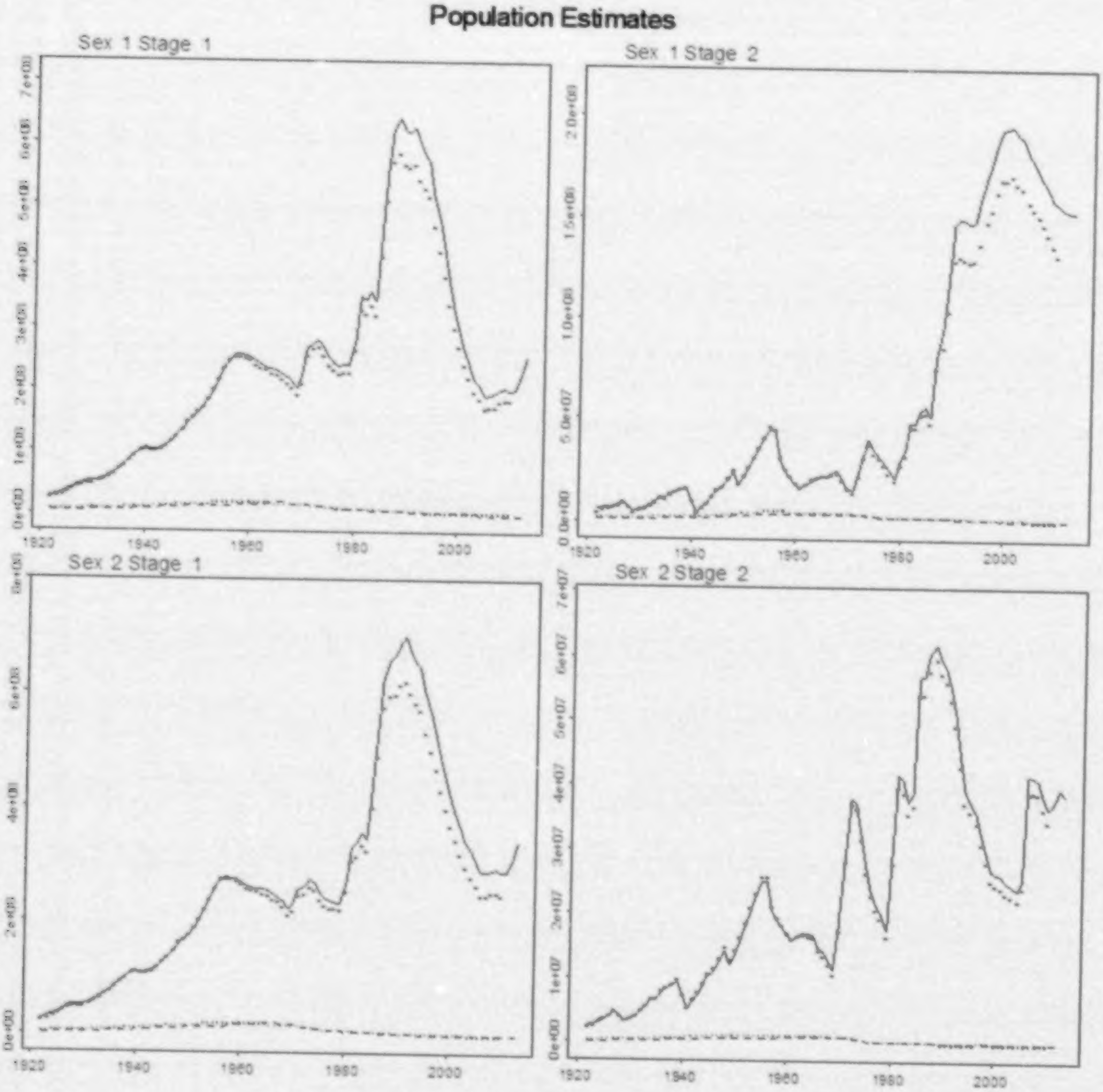


Figure 29. Abundance estimates (end of March) of population components from the updated 2013 model (straight line for US, dashed line for Canada) overlaid on estimates from the 2010 model (points for both regions).

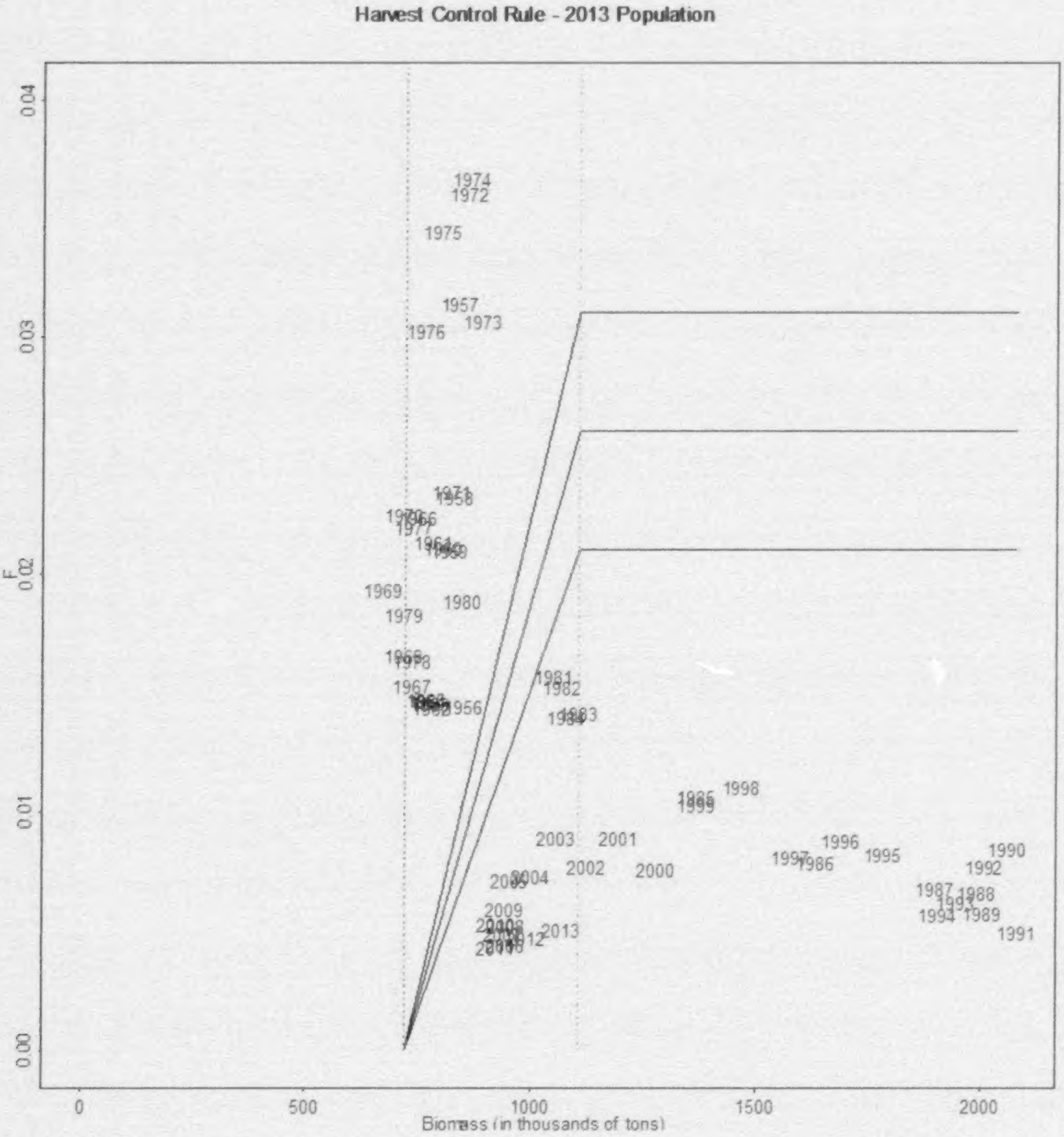


Figure 30. Harvest Control Rule (HCR) plot for total biomass and F_{MSY} from the updated dogfish population model. The lower reference point (LRP) is defined as 65% of B_{MSY} (dotted red line) and the upper reference point (URP) as B_{MSY} (dotted green line). Results for three assumed population growth rates are shown (bottom to top: r= .042, .052, .062).

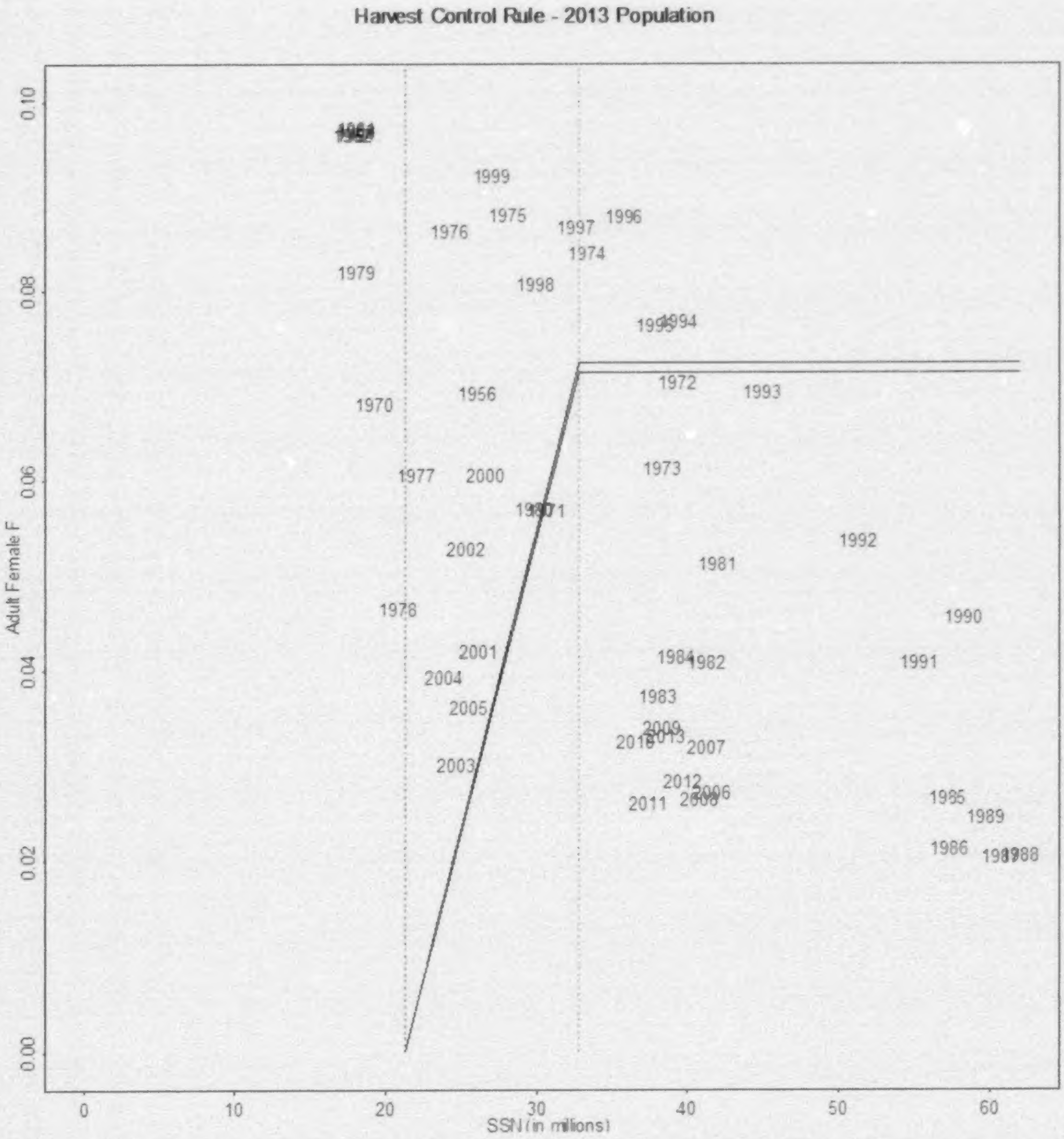


Figure 31. Harvest Control Rule (HCR) plot for SSN and F_{lim} from the updated dogfish population model. The lower reference point (LRP) is defined as 65% of B_{lim} (dotted red line) and the upper reference point (URP) as B_{lim} (dotted green line). Results for two assumed regional catch proportions are shown (bottom to top K ratio, catch ratio).

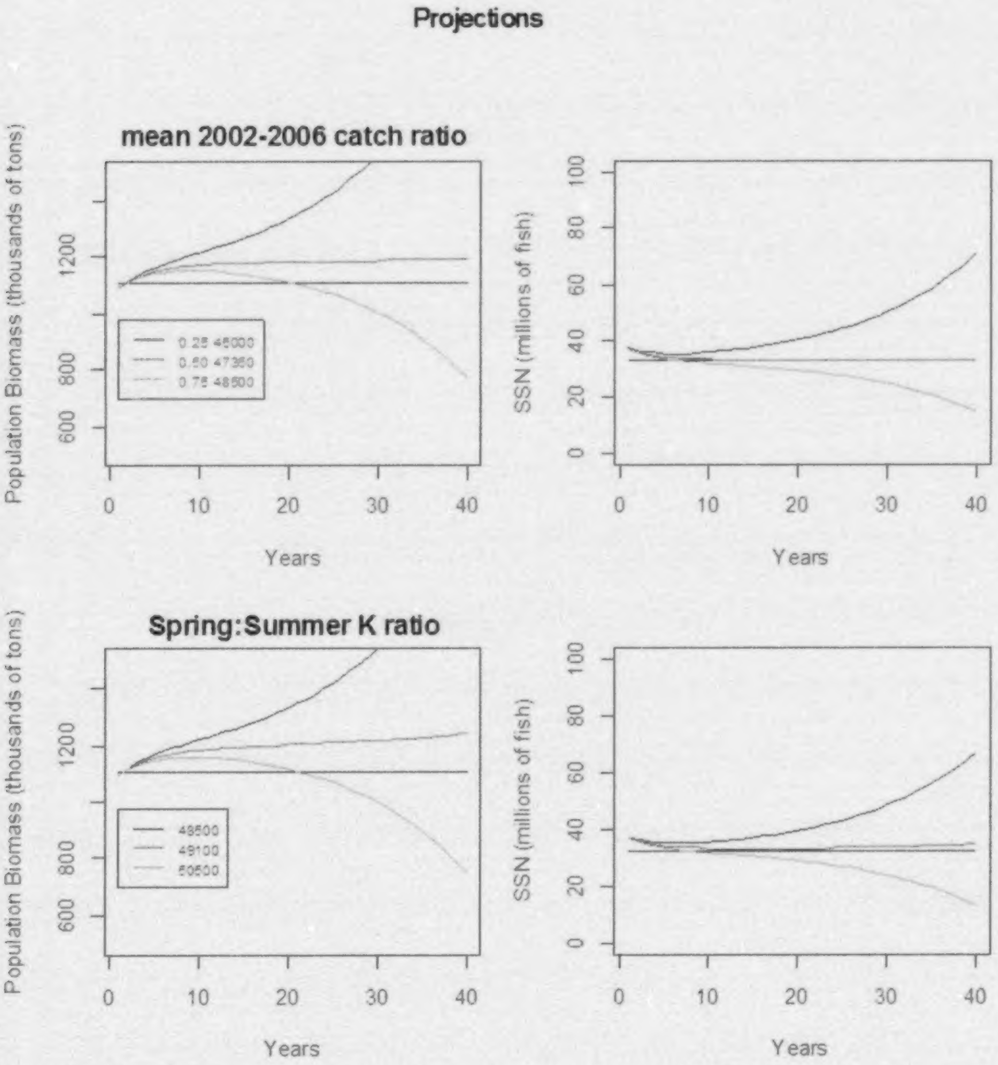
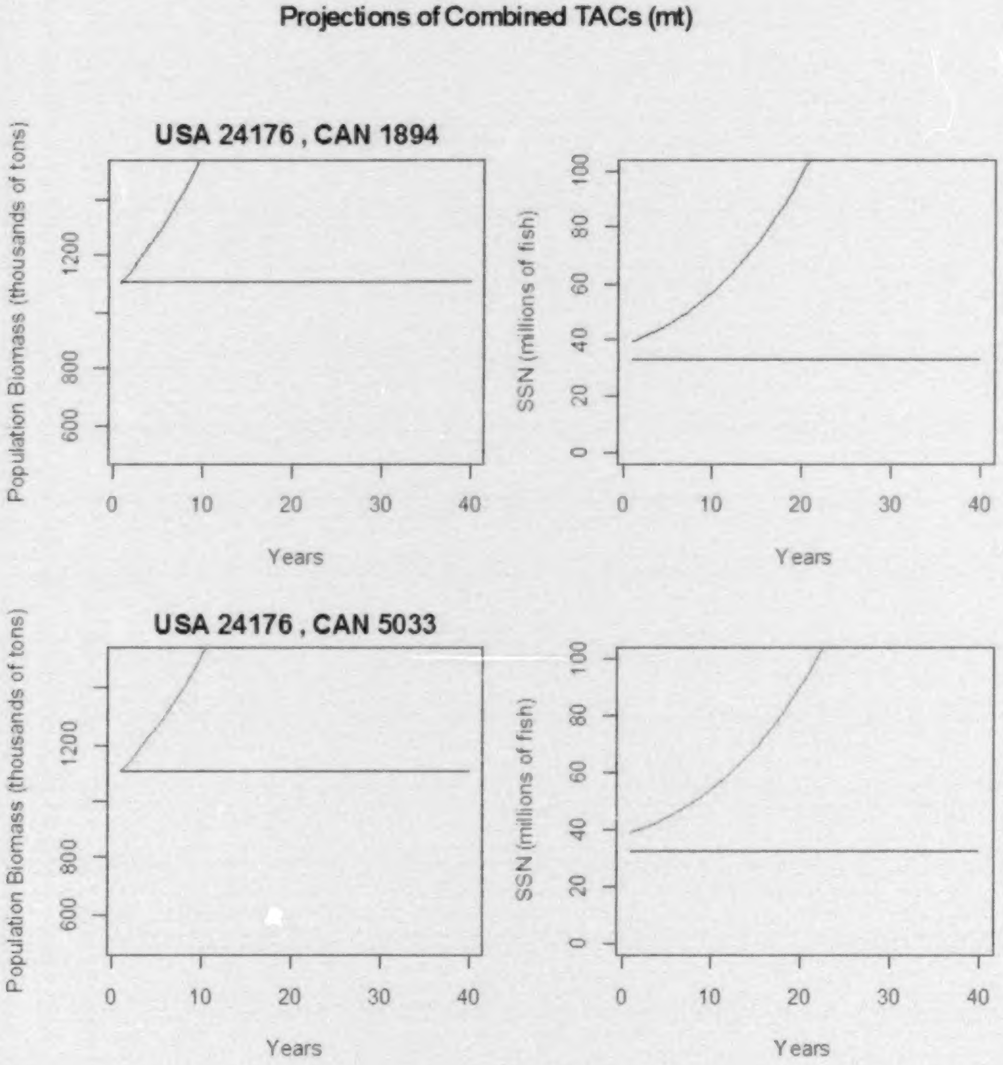


Figure 32. Projection results for regional catch levels according to catch ratio and K ratio methods. Catch levels were obtained for 25% (blue), 50% (red) and 75% (green) likelihoods of crossing an indicator threshold in year 40. Black horizontal lines represent B_{MSY} on biomass graphs and A_{lim} on SSN graphs.



Projections of Combined TACs (mt)

USA 24176 , CAN 1894

USA 24176 , CAN 5033

Figure 33. Projection results for Canadian TACs of 1894 mt (black curve) or 5033 mt (red curve) on top of the 2015 US TAL of 18869 mt. Black horizontal lines represent B_{MSY} on biomass graphs and A_{lim} on SSN graphs.

APPENDICES

APPENDIX 1. MODEL DESIGN

Process equations in sequence. The population dynamics were split into two periods to represent migrations and capture population estimates proximate to surveys. In addition, the sequencing of equations was adjusted to accommodate exploitation of migrant dogfish.

Index definitions:

Region = r; 1 = Canada, 2 = USA

Year = y; 1962 - 2010

Time step (season or period) = p; 1 = November - April, 2 = May - October

Sex = s; 1 = male, 2 = female

Maturity stage = m; 1 = juvenile, 2 = adult

Catch Equation for Fishery Removals (Landed Dogfish or Dead Discards):

$$\mathbf{Catch}_{rypsm} = (\mathbf{CatchAdjustmentFactor}_{ryp}/(\Sigma\ \mathbf{CatchProportion}_{ryp})) * \mathbf{CatchProportion}_{rypsm} * \mathbf{TotalCatchryp}$$

Population Dynamics Period 1 (November-April)

//transitions from juveniles to adults

$$\mathbf{N}_{ry[p=1]s[m=1]} = \mathbf{N}_{r[y-1][p=2]s[m=1]} * (\mathbf{1.0} - \mathbf{Theta}_{r[y-1]s})$$

$$\mathbf{N}_{ry[p=1]s[m=2]} = \mathbf{N}_{ry[p=1]s[m=2]} + (\mathbf{N}_{r[y-1][p=2]s[m=1]} * \mathbf{Theta}_{r[y-1]s})$$

//Canadian exploitation of Canadian dogfish components

$$\mathbf{ExploitationRate}_{[r=1]y[p=1]sm} = \mathbf{Catch}_{[r=1]y[p=1]sm} / \mathbf{N}_{[r=1]y[p=1]sm}$$

//proportion Canadian migrants in USA

$$\mathbf{PropCANinUSA} = (\mathbf{N}_{[r=1]y[p=1]sm} * (\mathbf{CANUSAProportionMigrate}_{sm} * \mathbf{CANUSAProportionMigrateDeviation}_{ysm}))/(\mathbf{N}_{[r=2]y[p=1]sm} + (\mathbf{N}_{[r=1]y[p=1]sm} * (\mathbf{CANUSAProportionMigrate}_{sm} * \mathbf{CANUSAProportionMigrateDeviation}_{ysm})))$$

//Add US exploitation of Canadian dogfish components

$$\mathbf{ExploitationRate}_{[r=1]y[p=1]sm} = \mathbf{ExploitationRate}_{[r=1]y[p=1]sm} + ((\mathbf{Catch}_{[r=2]y[p=1]sm} * \mathbf{PropCANinUSA}) / \mathbf{N}_{[r=1]y[p=1]sm})$$

// Canadian survival rates after catch and natural mortality (half-year);

$$\mathbf{SurvivalRate}_{[r=1]y[p=1]sm} = (\mathbf{1.0} - \mathbf{ExploitationRate}_{[r=1]y[p=1]sm}) * \mathbf{exp}(-\mathbf{natmort}_{m} * \mathbf{0.5})$$

$$\mathbf{N}_{[r=1]y[p=1]sm} = \mathbf{N}_{[r=1]y[p=1]sm} * \mathbf{SurvivalRate}_{[r=1]y[p=1]sm}$$

//US exploitation of US dogfish components

$$\mathbf{ExploitationRate}_{[r=2]y[p=1]sm} = (\mathbf{Catch}_{[r=2]y[p=1]sm} * (\mathbf{1.0}-\mathbf{PropCANinUSA})) / \mathbf{N}_{[r=2]y[p=1]sm}$$

//US survival rates after catch and natural mortality (half-year)

$$\textbf{SurvivalRate}_{[r=2]y[p=1]sm} = (\textbf{1.0 - ExploitationRate}_{[r=2]y[p=1]sm}) * \textbf{exp(-natmort}_{m} * \textbf{0.5)}$$

$$\textbf{N}_{[r=2]y[p=1]sm} = \textbf{N}_{[r=2]y[p=1]sm} * \textbf{SurvivalRate}_{[r=2]y[p=1]sm}$$

//Q-adjusted predictions end of season 1 to compare with survey observations

//Canadian survey is almost halfway through season 2; may want to adjust

//Floating Q if estimated annually (else Qdev always 1.0)

$$\textbf{PredictedSurveyAbundance}_{[r=2]y[p=1]sm} = (\textbf{N}_{[r=2]y[p=1]sm} + ((\textbf{CANUSAProportionMigrate}_{sm} * \textbf{CANUSAProportionMigrateDeviation}_{ysm}) * \textbf{N}_{[r=1]y[p=1]sm})) / (\textbf{exp(Q}_{[r=2]sm}) * \textbf{Qdev}_{[r=2]ysm})$$

$$\textbf{PredictedSurveyAbundance}_{[r=1]y[p=1]sm} = (\textbf{N}_{[r=1]y[p=1]sm} + ((\textbf{USACANProportionMigrate}_{sm} * \textbf{USACANProportionMigrateDeviation}_{ysm}) * \textbf{N}_{[r=2]y[p=1]sm})) / (\textbf{exp(Q}_{[r=1]sm}) * \textbf{Qdev}_{[r=1]ysm})$$

Population Dynamics Period 2 (May-October)

//recruitment at the start of the period (before migration)

//portions of USA components in Canadian region

//transitions from juveniles to adults

$$\textbf{N}_{ry[p=2]s[m=1]} = \textbf{N}_{ry[p-1]sm} * (\textbf{1.0 - Theta}_{rys})$$

$$\textbf{N}_{ry[p=2]s[m=2]} = \textbf{N}_{ry[p-1]sm} + (\textbf{N}_{ry[p-1]sm} * \textbf{Theta}_{rys})$$

//pups derive from females that lived to end of last season (maybe some dead would have pupped)

$$\textbf{Recruits}_{ry} = \textbf{N}_{ry[p=2][s=2][m=2]} * \textbf{PupsPerMom}_{ry} * \textbf{exp(-PupM)}$$

//recruitment 50:50 by sex

$$\textbf{N}_{ry[p=2]s[m=1]} = \textbf{N}_{ry[p=2]s[m=1]} + (\textbf{Recruits}_{ry} * \textbf{0.5})$$

//US exploitation of US dogfish component

$$\textbf{ExploitationRate}_{[r=2]y[p=2]sm} = \textbf{Catch}_{[r=2]y[p=2]sm} / \textbf{N}_{[r=2]y[p=2]sm}$$

//proportion USA migrants in Canada

$$\textbf{PropUSAinCAN} = (\textbf{N}_{[r=2]y[p=2]sm} * (\textbf{USACANProportionMigrate}_{sm} * \textbf{USACANProportionMigrateDeviation}_{ysm}))/(\textbf{N}_{[r=1]y[p=2]sm} + (\textbf{N}_{[r=2]y[p=2]sm} * (\textbf{USACANProportionMigrate}_{sm} * \textbf{USACANProportionMigrateDeviation}_{ysm})))$$

//Add Canadian exploitation of US dogfish components

$$\textbf{ExploitationRate}_{[r=2]y[p=2]sm} = \textbf{ExploitationRate}_{[r=2]y[p=2]sm} + ((\textbf{Catch}_{[r=1]y[p=2]sm} * \textbf{PropUSAinCAN}) / \textbf{N}_{[r=2]y[p=2]sm})$$

//USA survival rates after catch and natural mortality (half-year)

$$\textbf{SurvivalRate}_{[r=2]y[p=2]sm} = (\textbf{1.0 - ExploitationRate}_{[r=2]y[p=2]sm}) * \textbf{exp(-natmort}_{m} * \textbf{0.5)}$$

$$\mathbf{N}_{[r=2]y[p=2]sm} = \mathbf{N}_{[r=2]y[p=2]sm} * \mathbf{SurvivalRate}_{[r=2]y[p=2]sm}$$

//Canadian exploitation of Canadian dogfish components

ExploitationRate [r=1]y[p=2]sm = (Catch [r=1]y[p=2]sm * (1.0-PropUSAinCAN)) / N [r=1]y[p=2]sm

//Canadian survival rates after catch and natural mortality (half-year);

$$\mathbf{SurvivalRate}_{[r=1]y[p=2]sm} = \mathbf{(1.0 - ExploitationRate}_{[r=1]y[p=2]sm}\mathbf{) * exp(-natmort}_{m}\mathbf{ * 0.5)}$$

$$\mathbf{N}_{[r=1]y[p=2]sm} = \mathbf{N}_{[r=1]y[p=2]sm} * \mathbf{SurvivalRate}_{[r=1]y[p=2]sm}$$

APPENDIX 2. ADMB CODE FOR BASE MODEL

```
DATA_SECTION
    //Read the data file name from dog4s.ctl
    init_adstring datafile_name;
    //initial values etc;
    init_int retro_yrs;
    !! ad_comm::change_datafile_name(datafile_name);

    //Model dimensions
    init_int syr;
    init_int eyr;
    init_int nobs;
    init_vector it_yr(1,nobs);
    init_int scsyr;
    init_int ecsyr;
    init_int susyr;
    init_int eusyr;
    //Data
    init_int lengthbins;
    init_matrix usagrowthmat(1,nobs,1,3);
    init_matrix cangrowthmat(1,nobs,1,3);
    init_vector pups(1,nobs);
    init_vector cpups(1,nobs);
    init_vector sdrec(1,nobs);
    init_vector sdtheta(1,nobs);
    init_vector natmort(1,2);
    init_matrix maturity(1,lengthbins,1,3);
    //Survey numbers at length (row) by year (col); first col is length; separate matrices by survey and sex
    init_int csmalerecs;
    init_matrix csmaledata(1,csmalerecs,1,ecsyr-scsyr+2);
    init_int csfemalerecs;
    init_matrix csfemaledata(1,csfemalerecs,1,ecsyr-scsyr+2);
    init_int usmalerecs;
    init_matrix usmaledata(1,usmalerecs,1,eusyr-susyr+2);
    init_int usfemalerecs;
    init_matrix usfemaledata(1,usfemalerecs,1,eusyr-susyr+2);
    //Observed Survey Abundance grouped by sex and maturity for gauging fit
    init_vector obs_mj(47,nobs);
    init_vector obs_ma(47,nobs);
    init_vector obs_fj(47,nobs);
    init_vector obs_fa(47,nobs);
    init_vector Cobs_mj(49,nobs);
    init_vector Cobs_ma(49,nobs);
    init_vector Cobs_fj(49,nobs);
    init_vector Cobs_fa(49,nobs);
    //Catch numbers at length.
    //Detailed - not used in model.
    //Region Year Season Fishery CatchorDisc N T SD CAL=males*28 cols then females*28 cols
    init_int detcatchrecs;
    init_matrix detcatchdata(1,detcatchrecs,1,64);
    //Aggregated over Fisheries (including catch vs discard) - used in model.
    //Region Year Season SD CAL=males*28 cols then females*28 cols
    init_int catchrecs;
    init_matrix catchdata(1,catchrecs,1,60);
    //Observed Survey Errors USA & CAN
    init_vector stdev(47,nobs);
    init_vector Cstdev(49,nobs);
    //Catch grouped by sex, maturity and season for gauging fit
    init_vector CatchUSAMJ1(1,nobs);
    init_vector CatchUSAMA1(1,nobs);
    init_vector CatchUSAFJ1(1,nobs);
    init_vector CatchUSAFA1(1,nobs);
    init_vector CatchUSAMJ2(1,nobs);
    init_vector CatchUSAMA2(1,nobs);
    init_vector CatchUSAFJ2(1,nobs);
    init_vector CatchUSAFA2(1,nobs);
    init_vector CatchCANMJ1(1,nobs);
    init_vector CatchCANMA1(1,nobs);
    init_vector CatchCANFJ1(1,nobs);
    init_vector CatchCANFA1(1,nobs);
    init_vector CatchCANMJ2(1,nobs);
    init_vector CatchCANMA2(1,nobs);
    init_vector CatchCANFJ2(1,nobs);
    init_vector CatchCANFA2(1,nobs);
    //Catch Errors by region and season
    init_vector SDUSA1(1,nobs);
    init_vector SDUSA2(1,nobs);
    init_vector SDCAN1(1,nobs);
    init_vector SDCAN2(1,nobs);
    //Catch grouped by season for reallocating sex/stage composition
```

```
init_vector CatchUSA1(1,nobs);
init_vector CatchUSA2(1,nobs);
init_vector CatchCAN1(1,nobs);
init_vector CatchCAN2(1,nobs);
//End of data.
init_int eof;

LOC_CALCS
    if(eof != 42)
    {
        cout<<"Error reading data file.\n";
        exit(1);
    }
END_CALCS

//...END OF DATA FILE...

//reference points.
number bmsy;
number msy;
number umsy;
vector rstep(1,20);
vector zstep(1,20);
vector msystep(1,20);
vector bmsystep(1,20);
vector kstep(1,20);
vector fmsystep(1,20);
//population matrices
matrix N_m1(1,2,1,nobs);    //US males at length season 1
matrix N_m2(1,2,1,nobs);    //US males at length season 2
matrix N_f1(1,2,1,nobs);    //US females at length season 1
matrix N_f2(1,2,1,nobs);    //US females at length season 2
matrix CN_m1(1,2,1,nobs);   //CAN males at length season 1
matrix CN_m2(1,2,1,nobs);   //CAN males at length season 2
matrix CN_f1(1,2,1,nobs);   //CAN females at length season 1
matrix CN_f2(1,2,1,nobs);   //CAN females at length season 2
//set stages
int cqstagemj;
int cqstagefj;
int cqstagema;
int cqstagefa;
int mjcobserrstage;
int fjcobserrstage;
int macobserrstage;
int facobserrstage;
int qstagemj;
int qstagefj;
int qstagema;
int qstagefa;
int mjobserrstage;
int fjobserrstage;
int maobserrstage;
int faobserrstage;
int migstageucm;
int migstageucf;
int migstagecum;
int migstagecuf;
int vmigstageucm;
int vmigstageucf;
int vmigstagecum;
int vmigstagecuf;
int properrstageu1;
int properrstageu2;
int properrstagec1;
int properrstagec2;
int recstage;
int recstagec;
int thetastageu;
int thetastagec;
int catstage;
int pupmstage;
int fcqstagemj;
int fcqstagefj;
int fcqstagema;
int fcqstagefa;
int fqstagemj;
int fqstagefj;
int fqstagema;
int fqstagefa;
int nmstage;
int lastphase;
//phase to fit variables; use -99 for variables not in model
LOC_CALCS
    lastphase=0;
```

```
qstagemj=1;
qstagefj=1;
qstagema=1;
qstagefa=1;
fqstagemj=-99;
fqstagefj=-99;
fqstagema=-99;
fqstagefa=-99;
mjobserrstage=-99;
fjobserrstage=-99;
maobserrstage=-99;
faobserrstage=5;
cqstagemj=7;
cqstagefj=7;
cqstagema=7;
cqstagefa=7;
fcqstagemj=-9;
fcqstagefj=-9;
fcqstagema=-9;
fcqstagefa=-9;
mjcobserrstage=-99;
fjcobserrstage=-99;
macobserrstage=-99;
facobserrstage=8;
migstageucm=2;
migstageucf=2;
migstagecum=7;
migstagecuf=7;
vmigstageucm=2;
vmigstageucf=2;
vmigstagecum=-99;
vmigstagecuf=-99;
thetastageu=4;
thetastagec=9;
recstage=3;
recstagec=10;
pupmstage=6;
catstage=-99;
properrstageu1=-99;
properrstageu2=-99;
properrstagec1=-99;
properrstagec2=-99;
nmstage=-99;
if(qstagemj>lastphase)lastphase=qstagemj;
if(qstagefj>lastphase)lastphase=qstagefj;
if(qstagema>lastphase)lastphase=qstagema;
if(qstagefa>lastphase)lastphase=qstagefa;
if(mjobserrstage>lastphase)lastphase=mjobserrstage;
if(fjobserrstage>lastphase)lastphase=fjobserrstage;
if(maobserrstage>lastphase)lastphase=maobserrstage;
if(faobserrstage>lastphase)lastphase=faobserrstage;
if(cqstagemj>lastphase)lastphase=cqstagemj;
if(cqstagefj>lastphase)lastphase=cqstagefj;
if(cqstagema>lastphase)lastphase=cqstagema;
if(cqstagefa>lastphase)lastphase=cqstagefa;
if(mjcobserrstage>lastphase)lastphase=mjcobserrstage;
if(fjcobserrstage>lastphase)lastphase=fjcobserrstage;
if(macobserrstage>lastphase)lastphase=macobserrstage;
if(facobserrstage>lastphase)lastphase=facobserrstage;
if(migstageucm>lastphase)lastphase=migstageucm;
if(migstageucf>lastphase)lastphase=migstageucf;
if(migstagecum>lastphase)lastphase=migstagecum;
if(migstagecuf>lastphase)lastphase=migstagecuf;
if(vmigstageucm>lastphase)lastphase=vmigstageucm;
if(vmigstageucf>lastphase)lastphase=vmigstageucf;
if(vmigstagecum>lastphase)lastphase=vmigstagecum;
if(vmigstagecuf>lastphase)lastphase=vmigstagecuf;
if(recstage>lastphase)lastphase=recstage;
if(recstagec>lastphase)lastphase=recstagec;
if(pupmstage>lastphase)lastphase=pupmstage;
if(thetastageu>lastphase)lastphase=thetastageu;
if(thetastagec>lastphase)lastphase=thetastagec;
if(catstage>lastphase)lastphase=catstage;
if(properrstageu1>lastphase)lastphase=properrstageu1;
if(properrstageu2>lastphase)lastphase=properrstageu2;
if(properrstagec1>lastphase)lastphase=properrstagec1;
if(properrstagec2>lastphase)lastphase=properrstagec2;
if(fqstagemj>lastphase)lastphase=fqstagemj;
if(fqstagefj>lastphase)lastphase=fqstagefj;
if(fqstagema>lastphase)lastphase=fqstagema;
if(fqstagefa>lastphase)lastphase=fqstagefa;
if(fcqstagemj>lastphase)lastphase=fcqstagemj;
if(fcqstagefj>lastphase)lastphase=fcqstagefj;
if(fcqstagema>lastphase)lastphase=fcqstagema;
```

```
          if(fcqstagefa>lastphase)lastphase=fcqstagefa;
          if(nmstage>lastphase)lastphase=nmstage;
     END_CALCS

     int iters_phase1;
     int iters_phase2;
     int iters_phase3;
     int iters_phase4;
     int iters_phase5;
     int iters_phase6;
     int iters_phase7;
     !! iters_phase1=0;
     !! iters_phase2=0;
     !! iters_phase3=0;
     !! iters_phase4=0;
     !! iters_phase5=0;
     !! iters_phase6=0;

     //assumed error on mgration as log SD (0.2 constrained,0.6 loose)
     int ProjYrs;
     !! ProjYrs = 100;
     number sdmig;
     !! sdmig = 0.6;
     number sdq;
     !! sdq = 0.6;
     number eps;
     !! eps = 0.0001;

INITIALIZATION_SECTION
   //placeholder - using pin

PARAMETER_SECTION

     //survey catchability (separate by sex and stage)
     //init_bounded_number CANlogq_mj(-5.0,0.2,cqstagemj); reminder of bounds that allow for herding
     init_bounded_number CANlogqATC_mj(-5.0,0.0,cqstagemj);
     init_bounded_number CANlogqATC_ma(-5.0,0.0,cqstagema);
     init_bounded_number CANlogqATC_fj(-5.0,0.0,cqstagefj);
     init_bounded_number CANlogqATC_fa(-5.0,0.0,cqstagefa);
     init_bounded_number CANlogq_mj(-5.0,0.0,cqstagemj);
     init_bounded_number CANlogq_ma(-5.0,0.0,cqstagema);
     init_bounded_number CANlogq_fj(-5.0,0.0,cqstagefj);
     init_bounded_number CANlogq_fa(-5.0,0.0,cqstagefa);
     init_bounded_number USAlogq1_mj(-5.0,0.0,qstagemj);
     init_bounded_number USAlogq1_ma(-5.0,0.0,qstagema);
     init_bounded_number USAlogq1_fj(-5.0,0.0,qstagefj);
     init_bounded_number USAlogq1_fa(-5.0,0.0,qstagefa);
     init_bounded_number USAlogq2_mj(-5.0,0.0,qstagemj);
     init_bounded_number USAlogq2_ma(-5.0,0.0,qstagema);
     init_bounded_number USAlogq2_fj(-5.0,0.0,qstagefj);
     init_bounded_number USAlogq2_fa(-5.0,0.0,qstagefa);
     init_bounded_number USAlogq3_mj(-5.0,0.0,qstagemj);
     init_bounded_number USAlogq3_ma(-5.0,0.0,qstagema);
     init_bounded_number USAlogq3_fj(-5.0,0.0,qstagefj);
     init_bounded_number USAlogq3_fa(-5.0,0.0,qstagefa);
     init_bounded_number USAlogq4_mj(-5.0,0.0,qstagemj);
     init_bounded_number USAlogq4_ma(-5.0,0.0,qstagema);
     init_bounded_number USAlogq4_fj(-5.0,0.0,qstagefj);
     init_bounded_number USAlogq4_fa(-5.0,0.0,qstagefa);
     //annual deviates on the Q's (diagnostic, not for model);
     init_bounded_vector fCANlogq_mj(1,nobs,0.5,1.5,fcqstagemj);
     init_bounded_vector fCANlogq_ma(1,nobs,0.5,1.5,fcqstagema);
     init_bounded_vector fCANlogq_fj(1,nobs,0.5,1.5,fcqstagefj);
     init_bounded_vector fCANlogq_fa(1,nobs,0.5,1.5,fcqstagefa);
     init_bounded_vector fUSAlogq_mj(1,nobs,0.5,1.5,fqstagemj);
     init_bounded_vector fUSAlogq_ma(1,nobs,0.5,1.5,fqstagema);
     init_bounded_vector fUSAlogq_fj(1,nobs,0.5,1.5,fqstagefj);
     init_bounded_vector fUSAlogq_fa(1,nobs,0.5,1.5,fqstagefa);
     //migration (separate by sex and stage)
     init_bounded_vector UCmigration_m(1,2,0.0001,0.5,migstageucm);
     init_bounded_vector UCmigration_f(1,2,0.0001,0.5,migstageucf);
     init_bounded_vector CUmigration_m(1,2,0.0001,0.5,migstagecum);
     init_bounded_vector CUmigration_f(1,2,0.0001,0.5,migstagecuf);
     init_bounded_matrix varUCmigration_m(1,2,47,nobs,0.1,1.9,vmigstageucm);
     init_bounded_matrix varUCmigration_f(1,2,47,nobs,0.1,1.9,vmigstageucf);
     init_bounded_matrix varCUmigration_m(1,2,47,nobs,0.1,1.9,vmigstagecum);
     init_bounded_matrix varCUmigration_f(1,2,47,nobs,0.1,1.9,vmigstagecuf);
     //priors for initial abundance - USA; commenting out approach that estimates the components independently
     //init_bounded_number N_mj(0000000,750000000,mjobserrstage);       //US males at stage 1
     //init_bounded_number N_ma(0000000,750000000,maobserrstage);       //US males at stage 2
     //init_bounded_number N_fj(0000000,750000000,fjobserrstage);       //US females at stage 1
     //init_bounded_number N_fa(0000000,750000000,faobserrstage);       //US females at stage 2
     //init_bounded_number N_Total(log(10000),log(10000000000),faobserrstage);       //Total Population
     init_bounded_number N_Total(0,9.2,faobserrstage);    //Total Population
```

```
    //priors for initial abundance - CAN; done as proportions of USA pop; commenting out approach that
estimates the components independently
    //init_bounded_number CN_mj(0.01,0.12,mjcobserrstage);    //CAN males at stage 1
    //init_bounded_number CN_ma(0.01,0.12,macobserrstage);    //CAN males at stage 2
    //init_bounded_number CN_fj(0.01,0.12,fjcobserrstage);    //CAN females at stage 1
    //init_bounded_number CN_fa(0.01,0.12,facobserrstage);    //CAN females at stage 2
    init_bounded_number CN_fa(0.01,1.0,facobserrstage);  //proportions of USA pop
    //Prior for recruitment rate adjustment; pup multiplier (CAN,USA)
    init_bounded_vector pupfac(35,nobs,2.1,7.0,recstage);
    init_bounded_vector cpupfac(35,nobs,2.1,7.0,recstagec);
    init_bounded_number pupm(0.0,0.5,pupmstage); //extra pup M
    //uninformative priors for CAS as relative proportions of total; sum(props)/1 gives absolute proportions;
row sequence mj ma fj fa
    //0.0-0.25 imposes a cap at the total cap (4*0.25); if we want to allow for total catch underestimation we
would increase the upper bound
    init_bounded_matrix propusa1(1,4,1,nobs,0.0,1.0,properrstageu1);  //US season 1 proportions catch by
sex/stage
    init_bounded_matrix propusa2(1,4,1,nobs,0.0,1.0,properrstageu2);  //US season 2 proportions catch by
sex/stage
    init_bounded_matrix propcan1(1,4,1,nobs,0.0,1.0,properrstagec1);  //CAN season 1 proportions catch by
sex/stage
    init_bounded_matrix propcan2(1,4,1,nobs,0.0,1.0,properrstagec2);  //CAN season 2 proportions catch by
sex/stage
    //give theta some wiggle room;US m f CAN m f
    init_bounded_matrix thetavarusa(1,2,35,nobs,0.000,0.04,thetastageu);
    init_bounded_matrix thetavarcan(1,2,35,nobs,0.000,0.04,thetastagec);
    //give total catch some wiggle room
    init_bounded_vector catchfaccan1(1,nobs,0.75,1.05,catstage); //CAN season 1
    init_bounded_vector catchfaccan2(1,nobs,0.75,1.05,catstage); //CAN season 2
    init_bounded_vector catchfacusa1(1,nobs,0.75,1.05,catstage); //USA season 1
    init_bounded_vector catchfacusa2(1,nobs,0.75,1.05,catstage); //USA season 2
    //estimate M
    init_bounded_vector natmortm(1,2,0.09,0.15,nmstage); //male M by stage
    init_bounded_vector natmortf(1,2,0.09,0.15,nmstage); //female M by stage

    objective_function_value f;

    //population matrices
    matrix N_m1(1,2,1,nobs+ProjYrs);     //US males at stage season 1
    matrix N_m2(1,2,1,nobs+ProjYrs);     //US males at stage season 2
    matrix N_f1(1,2,1,nobs+ProjYrs);     //US females at stage season 1
    matrix N_f2(1,2,1,nobs+ProjYrs);     //US females at stage season 2
    matrix CN_m1(1,2,1,nobs+ProjYrs);    //CAN males at stage season 1
    matrix CN_m2(1,2,1,nobs+ProjYrs);    //CAN males at stage season 2
    matrix CN_f1(1,2,1,nobs+ProjYrs);    //CAN females at stage season 1
    matrix CN_f2(1,2,1,nobs+ProjYrs);    //CAN females at stage season 2

    matrix c_m1(1,2,1,nobs+ProjYrs);     //US males at stage season 1
    matrix c_m2(1,2,1,nobs+ProjYrs);     //US males at stage season 2
    matrix c_f1(1,2,1,nobs+ProjYrs);     //US females at stage season 1
    matrix c_f2(1,2,1,nobs+ProjYrs);     //US females at stage season 2
    matrix Cc_m1(1,2,1,nobs+ProjYrs);    //CAN males at stage season 1
    matrix Cc_m2(1,2,1,nobs+ProjYrs);    //CAN males at stage season 2
    matrix Cc_f1(1,2,1,nobs+ProjYrs);    //CAN females at stage season 1
    matrix Cc_f2(1,2,1,nobs+ProjYrs);    //CAN females at stage season 2

    matrix exploit_m1(1,2,1,nobs+ProjYrs);
    matrix exploit_m2(1,2,1,nobs+ProjYrs);
    matrix exploit_f1(1,2,1,nobs+ProjYrs);
    matrix exploit_f2(1,2,1,nobs+ProjYrs);
    matrix Cexploit_m1(1,2,1,nobs+ProjYrs);
    matrix Cexploit_m2(1,2,1,nobs+ProjYrs);
    matrix Cexploit_f1(1,2,1,nobs+ProjYrs);
    matrix Cexploit_f2(1,2,1,nobs+ProjYrs);
    matrix tmp_m1(1,2,1,nobs+ProjYrs);
    matrix tmp_m2(1,2,1,nobs+ProjYrs);
    matrix tmp_f1(1,2,1,nobs+ProjYrs);
    matrix tmp_f2(1,2,1,nobs+ProjYrs);
    matrix Ctmp_m1(1,2,1,nobs+ProjYrs);
    matrix Ctmp_m2(1,2,1,nobs+ProjYrs);
    matrix Ctmp_f1(1,2,1,nobs+ProjYrs);
    matrix Ctmp_f2(1,2,1,nobs+ProjYrs);
    matrix n_m1(1,2,1,nobs+ProjYrs);
    matrix n_m2(1,2,1,nobs+ProjYrs);
    matrix n_f1(1,2,1,nobs+ProjYrs);
    matrix n_f2(1,2,1,nobs+ProjYrs);
    matrix Cn_m1(1,2,1,nobs+ProjYrs);
    matrix Cn_m2(1,2,1,nobs+ProjYrs);
    matrix Cn_f1(1,2,1,nobs+ProjYrs);
    matrix Cn_f2(1,2,1,nobs+ProjYrs);
    //predicted abundances (q-adjusted) for survey fitting
    matrix Im_mUSA(1,2,1,nobs);
    matrix Im_mCAN(1,2,1,nobs);
    matrix Im_fUSA(1,2,1,nobs);
matrix Im_fCAN(1,2,1,nobs);
//predicted recruits, Can & US;
vector estrec(1,nobs+ProjYrs);
vector Cestrec(1,nobs+ProjYrs);
//residuals for recruits, survey years, Can & US
vector resrec(1,eusyr-susyr+1);
vector Cresrec(1,ecsyr-scsyr+1);
//residuals for recruits as pups per mom
vector pupresrec(35,nobs);
vector cpupresrec(35,nobs);
//predicted proportions pelagic juveniles in 2nd-6th yrs
vector propavail(1,nobs);
//predicted population components
vector USAMJ(1,nobs+ProjYrs);
vector USAMA(1,nobs+ProjYrs);
vector USAFJ(1,nobs+ProjYrs);
vector USAFA(1,nobs+ProjYrs);
vector CANMJ(1,nobs+ProjYrs);
vector CANMA(1,nobs+ProjYrs);
vector CANFJ(1,nobs+ProjYrs);
vector CANFA(1,nobs+ProjYrs);
//predicted catch components (by season)
vector PredCatchUSAMJ1(1,nobs);
vector PredCatchUSAMA1(1,nobs);
vector PredCatchUSAFJ1(1,nobs);
vector PredCatchUSAFA1(1,nobs);
vector PredCatchCANMJ1(1,nobs);
vector PredCatchCANMA1(1,nobs);
vector PredCatchCANFJ1(1,nobs);
vector PredCatchCANFA1(1,nobs);
vector PredCatchUSAMJ2(1,nobs);
vector PredCatchUSAMA2(1,nobs);
vector PredCatchUSAFJ2(1,nobs);
vector PredCatchUSAFA2(1,nobs);
vector PredCatchCANMJ2(1,nobs);
vector PredCatchCANMA2(1,nobs);
vector PredCatchCANFJ2(1,nobs);
vector PredCatchCANFA2(1,nobs);
//residuals for maturity thetas
vector errthetamale(35,nobs);
vector errthetafemale(35,nobs);
vector cerrthetamale(35,nobs);
vector cerrthetafemale(35,nobs);
//residuals for migration
vector errcumigjm(47,nobs);
vector errcumigam(47,nobs);
vector errcumigjf(47,nobs);
vector errcumigaf(47,nobs);
vector errucmigjm(47,nobs);
vector errucmigam(47,nobs);
vector errucmigjf(47,nobs);
vector errucmigaf(47,nobs);
number sdcumigjm;
number sdcumigam;
number sdcumigjf;
number sdcumigaf;
number sducmigjm;
number sducmigam;
number sducmigjf;
number sducmigaf;
number sdq1;
number sdq2;
number sdq3;
number sdq4;
number sdq5;
number sdq6;
number sdq7;
number sdq8;

vector fvecout(1,824);


vector resmj(47,nobs);    //survey residuals USA
vector resma(47,nobs);    //survey residuals USA
vector resfj(47,nobs);    //survey residuals USA
vector resfa(47,nobs);    //survey residuals USA
vector resmjc(49,nobs);   //survey residuals Canada
vector resmac(49,nobs);   //survey residuals Canada
vector resfjc(49,nobs);   //survey residuals Canada
vector resfac(49,nobs);   //survey residuals Canada
number sdmj; //survey std
number sdma; //survey std
number sdfj; //survey std
number sdfa; //survey std
```

```
   number sdmjc;     //survey std
   number sdmac;     //survey std
   number sdfjc;     //survey std
   number sdfac;     //survey std
   vector catchresmj1(1,nobs);   //catch residuals USA
   vector catchresma1(1,nobs);   //catch residuals USA
   vector catchresfj1(1,nobs);   //catch residuals USA
   vector catchresfa1(1,nobs);   //catch residuals USA
   vector catchresmjc1(1,nobs);  //catch residuals Canada
   vector catchresmac1(1,nobs);  //catch residuals Canada
   vector catchresfjc1(1,nobs);  //catch residuals Canada
   vector catchresfac1(1,nobs);  //catch residuals Canada
   vector catchresmj2(1,nobs);   //catch residuals USA
   vector catchresma2(1,nobs);   //catch residuals USA
   vector catchresfj2(1,nobs);   //catch residuals USA
   vector catchresfa2(1,nobs);   //catch residuals USA
   vector catchresmjc2(1,nobs);  //catch residuals Canada
   vector catchresmac2(1,nobs);  //catch residuals Canada
   vector catchresfjc2(1,nobs);  //catch residuals Canada
   vector catchresfac2(1,nobs);  //catch residuals Canada
   number catchsdmj1;    //catch std
   number catchsdma1;    //catch std
   number catchsdfj1;    //catch std
   number catchsdfa1;    //catch std
   number catchsdmjc1;   //catch std
   number catchsdmac1;   //catch std
   number catchsdfjc1;   //catch std
   number catchsdfac1;   //catch std
   number catchsdmj2;    //catch std
   number catchsdma2;    //catch std
   number catchsdfj2;    //catch std
   number catchsdfa2;    //catch std
   number catchsdmjc2;   //catch std
   number catchsdmac2;   //catch std
   number catchsdfjc2;   //catch std
   number catchsdfac2;   //catch std

   number sdpmj;     //survey process std
   number sdpma;     //survey process std
   number sdpfj;     //survey process std
   number sdpfa;     //survey process std
   number sdprec;   //recruitment process std
   number csdprec;  //recruitment process std
   number sdthetamale;   //male maturity transition process std
   number sdthetafemale; //female maturity transition process std
   number csdthetamale;  //male maturity transition process std
   number csdthetafemale;     //female maturity transition process std

   number bo;
   number reck;
   number q;
   number tau;

   number a;    //BH initial slope
   number b;    //BH capacity parameter.
   //Penalty to ensure positive biomass
   vector fpensm1(1,nobs);
   vector fpensm2(1,nobs);
   vector fpensf1(1,nobs);
   vector fpensf2(1,nobs);
   vector Cfpensm1(1,nobs);
   vector Cfpensm2(1,nobs);
   vector Cfpensf1(1,nobs);
   vector Cfpensf2(1,nobs);
   vector fpenrec(1,nobs+ProjYrs);//Penalty to ensure positive recruitment
   matrix fpenprop(1,8,1,nobs+ProjYrs);//Penalty on Q deviates (not for model)
   vector projfpensm1(nobs+1,nobs+ProjYrs);
   vector projfpensm2(nobs+1,nobs+ProjYrs);
   vector projfpensf1(nobs+1,nobs+ProjYrs);
   vector projfpensf2(nobs+1,nobs+ProjYrs);
   vector projCfpensm1(nobs+1,nobs+ProjYrs);
   vector projCfpensm2(nobs+1,nobs+ProjYrs);
   vector projCfpensf1(nobs+1,nobs+ProjYrs);
   vector projCfpensf2(nobs+1,nobs+ProjYrs);
matrix vCsm1(1,nobs+ProjYrs,1,2);  //Canadian male survival rate from fishing season 1
matrix vCsf1(1,nobs+ProjYrs,1,2);  //Canadian female survival rate from fishing season 1
matrix vCsm2(1,nobs+ProjYrs,1,2);  //Canadian male survival rate from fishing season 2
matrix vCsf2(1,nobs+ProjYrs,1,2);  //Canadian female survival rate from fishing season 2
matrix vsm1(1,nobs+ProjYrs,1,2);  //US male survival rate from fishing season 1
matrix vsf1(1,nobs+ProjYrs,1,2);  //US female survival rate from fishing season 1
matrix vsm2(1,nobs+ProjYrs,1,2);  //US male survival rate from fishing season 2
matrix vsf2(1,nobs+ProjYrs,1,2);  //US female survival rate from fishing season 2

   sdreport_matrix projpop(nobs+1,nobs+ProjYrs,1,16);
```

```
    sdreport_matrix totprojpop(nobs+1,nobs+ProjYrs,1,8);


PRELIMINARY_CALCS_SECTION
    //dep.set_stepsize(0.7); // default value is 0.5; the number represents x * the std dev of the parameter

PROCEDURE_SECTION
  fpensm1.initialize();
  fpensf1.initialize();
  Cfpensm1.initialize();
  Cfpensf1.initialize();
  fpensm2.initialize();
  fpensf2.initialize();
  Cfpensm2.initialize();
  Cfpensf2.initialize();
  estrec.initialize();
  Cestrec.initialize();
  fpenprop.initialize();

    //** Main Function Calls **//

    pop_dyn();
    calc_obj_func();

//Increment iteration counters
  if(current_phase()==1) iters_phase1++;
  if(current_phase()==2) iters_phase2++;
  if(current_phase()==3) iters_phase3++;
  if(current_phase()==4) iters_phase4++;
  if(current_phase()==5) iters_phase5++;
  if(current_phase()==6) iters_phase6++;
  if(current_phase()==7) iters_phase7++;

FUNCTION pop_dyn
  //
  dvar_matrix Csm1(1,nobs+ProjYrs,1,2);  //Canadian male survival rate from fishing season 1
  dvar_matrix Csf1(1,nobs+ProjYrs,1,2);  //Canadian female survival rate from fishing season 1
  dvar_matrix Csm2(1,nobs+ProjYrs,1,2);  //Canadian male survival rate from fishing season 2
  dvar_matrix Csf2(1,nobs+ProjYrs,1,2);  //Canadian female survival rate from fishing season 2
  dvar_matrix sm1(1,nobs+ProjYrs,1,2);  //US male survival rate from fishing season 1
  dvar_matrix sf1(1,nobs+ProjYrs,1,2);  //US female survival rate from fishing season 1
  dvar_matrix sm2(1,nobs+ProjYrs,1,2);  //US male survival rate from fishing season 2
  dvar_matrix sf2(1,nobs+ProjYrs,1,2);  //US female survival rate from fishing season 2
  int t;
  for (t=1; t<=92; t++) {
  Cc_m1(1,t) = (catchfaccan1(t)/(propcan1(1,t)+propcan1(2,t)+propcan1(3,t)+propcan1(4,t))) *
propcan1(1,t)*CatchCAN1(t);
  Cc_m1(2,t) = (catchfaccan1(t)/(propcan1(1,t)+propcan1(2,t)+propcan1(3,t)+propcan1(4,t))) *
propcan1(2,t)*CatchCAN1(t);
  Cc_f1(1,t) = (catchfaccan1(t)/(propcan1(1,t)+propcan1(2,t)+propcan1(3,t)+propcan1(4,t))) *
propcan1(3,t)*CatchCAN1(t);
  Cc_f1(2,t) = (catchfaccan1(t)/(propcan1(1,t)+propcan1(2,t)+propcan1(3,t)+propcan1(4,t))) *
propcan1(4,t)*CatchCAN1(t);
  Cc_m2(1,t) = (catchfaccan2(t)/(propcan2(1,t)+propcan2(2,t)+propcan2(3,t)+propcan2(4,t))) *
propcan2(1,t)*CatchCAN2(t);
  Cc_m2(2,t) = (catchfaccan2(t)/(propcan2(1,t)+propcan2(2,t)+propcan2(3,t)+propcan2(4,t))) *
propcan2(2,t)*CatchCAN2(t);
  Cc_f2(1,t) = (catchfaccan2(t)/(propcan2(1,t)+propcan2(2,t)+propcan2(3,t)+propcan2(4,t))) *
propcan2(3,t)*CatchCAN2(t);
  Cc_f2(2,t) = (catchfaccan2(t)/(propcan2(1,t)+propcan2(2,t)+propcan2(3,t)+propcan2(4,t))) *
propcan2(4,t)*CatchCAN2(t);
  c_m1(1,t) = (catchfacusa1(t)/(propusa1(1,t)+propusa1(2,t)+propusa1(3,t)+propusa1(4,t))) *
propusa1(1,t)*CatchUSA1(t);
  c_m1(2,t) = (catchfacusa1(t)/(propusa1(1,t)+propusa1(2,t)+propusa1(3,t)+propusa1(4,t))) *
propusa1(2,t)*CatchUSA1(t);
  c_f1(1,t) = (catchfacusa1(t)/(propusa1(1,t)+propusa1(2,t)+propusa1(3,t)+propusa1(4,t))) *
propusa1(3,t)*CatchUSA1(t);
  c_f1(2,t) = (catchfacusa1(t)/(propusa1(1,t)+propusa1(2,t)+propusa1(3,t)+propusa1(4,t))) *
propusa1(4,t)*CatchUSA1(t);
  c_m2(1,t) = (catchfacusa2(t)/(propusa2(1,t)+propusa2(2,t)+propusa2(3,t)+propusa2(4,t))) *
propusa2(1,t)*CatchUSA2(t);
  c_m2(2,t) = (catchfacusa2(t)/(propusa2(1,t)+propusa2(2,t)+propusa2(3,t)+propusa2(4,t))) *
propusa2(2,t)*CatchUSA2(t);
  c_f2(1,t) = (catchfacusa2(t)/(propusa2(1,t)+propusa2(2,t)+propusa2(3,t)+propusa2(4,t))) *
propusa2(3,t)*CatchUSA2(t);
  c_f2(2,t) = (catchfacusa2(t)/(propusa2(1,t)+propusa2(2,t)+propusa2(3,t)+propusa2(4,t))) *
propusa2(4,t)*CatchUSA2(t);
  }
  int lb;
    dvariable propfor;
    dvariable mstay;
    dvariable mmoveon;
    dvariable fstay;
    dvariable fmoveon;
    dvariable Cmstay;
    dvariable Cmmoveon;
    dvariable Cfstay;
    dvariable Cfmoveon;
    //estimated composition; commenting out approach that estimates components independently
    //N_m1(1,1) = N_mj;
    //N_m1(2,1) = N_ma;
    //N_f1(1,1) = N_fj;
    //N_f1(2,1) = N_fa;
    //CN_m1(1,1) = CN_mj*N_mj;
    //CN_m1(2,1) = CN_ma*N_ma;
    //CN_f1(1,1) = CN_fj*N_fj;
    //CN_f1(2,1) = CN_fa*N_fa;
    //length-based stable composition (hardly differs from age-based)
    //N_m1(1,1) = 0.43*N_Total;
    //N_m1(2,1) = 0.06*N_Total;
    //N_f1(1,1) = 0.47*N_Total;
    //N_f1(2,1) = 0.04*N_Total;
    //age-based stable composition
    N_m1(1,1) = 0.42*mfexp(N_Total)*1000000;
    N_m1(2,1) = 0.08*mfexp(N_Total)*1000000;
    N_f1(1,1) = 0.46*mfexp(N_Total)*1000000;
    N_f1(2,1) = 0.04*mfexp(N_Total)*1000000;
    //Making the Canadian proportion a constant (just using CN_fa) to preserve the composition
    CN_m1(1,1) = CN_fa*N_m1(1,1);
    CN_m1(2,1) = CN_fa*N_m1(2,1);
    CN_f1(1,1) = CN_fa*N_f1(1,1);
    CN_f1(2,1) = CN_fa*N_f1(2,1);
   //estimated transition from juvenile to adult
   //juvenile males remaining juveniles
   mstay = N_m1(1,1)*(1.0-usagrowthmat(1,2));
   //juvenile males becoming mature
   mmoveon = N_m1(1,1)*usagrowthmat(1,2);
   //juvenile females remaining juveniles
   fstay = N_f1(1,1)*(1.0-usagrowthmat(1,3));
   //juvenile females becoming mature
   fmoveon = N_f1(1,1)*usagrowthmat(1,3);
   Cmstay = CN_m1(1,1)*(1.0-cangrowthmat(1,2));
   Cmmoveon = CN_m1(1,1)*cangrowthmat(1,2);
   Cfstay = CN_f1(1,1)*(1.0-cangrowthmat(1,3));
   Cfmoveon = CN_f1(1,1)*cangrowthmat(1,3);
   Ctmp_m1(1,1) = Cmstay;
   Ctmp_m1(2,1) = CN_m1(2,1)+Cmmoveon;
   Ctmp_f1(1,1) = Cfstay;
   Ctmp_f1(2,1) = CN_f1(2,1)+Cfmoveon;
   tmp_m1(1,1) = mstay;
   tmp_m1(2,1) = N_m1(2,1)+mmoveon;
   tmp_f1(1,1) = fstay;
   tmp_f1(2,1) = N_f1(2,1)+fmoveon;
    //season 1 (portions of CAN component in USA region, so CAN first)
  for (lb=1; lb<=2; lb++) {
    //CAN component & fishery
   //CAN male removals at stage by CAN fishery
   Cexploit_m1(lb,1) = Cc_m1(lb,1) / Ctmp_m1(lb,1);
   //females
   Cexploit_f1(lb,1) = Cc_f1(lb,1) / Ctmp_f1(lb,1);
    //USA component & fishery + CAN component
   //proportion CAN male migrants in USA
   propfor = (Ctmp_m1(lb,1) * (CUmigration_m(lb)))/(tmp_m1(lb,1)+(Ctmp_m1(lb,1) * (CUmigration_m(lb))));
   //USA male removals at stage by USA fishery
   exploit_m1(lb,1) = c_m1(lb,1)*(1.0-propfor) / tmp_m1(lb,1);
   //CAN male removals at stage by USA fishery
   Cexploit_m1(lb,1) = Cexploit_m1(lb,1) + ((c_m1(lb,1)*propfor) / Ctmp_m1(lb,1));
   //USA male survival at stage after catch and natural mortality (half-year); cannot be zero, they still exist
   sm1(1,lb) = posfun((1. - exploit_m1(lb,1)) * mfexp(-natmortm(lb)*0.5),eps,fpensm1(1));
   n_m1(lb,1) = log(tmp_m1(lb,1) * sm1(1,lb));
   N_m1(lb,1) = mfexp(n_m1(lb,1));
   //CAN male survival at stage after catch and natural mortality (half-year); cannot be zero, they still exist
   Csm1(1,lb) = posfun((1. - Cexploit_m1(lb,1)) * mfexp(-natmortm(lb)*0.5),eps,Cfpensm1(1));
   Cn_m1(lb,1) = log(Ctmp_m1(lb,1) * Csm1(1,lb));
   CN_m1(lb,1) = mfexp(Cn_m1(lb,1));
   //females
   //proportion CAN female migrants in USA
   propfor = (Ctmp_f1(lb,1) * (CUmigration_f(lb)))/(tmp_f1(lb,1)+(Ctmp_f1(lb,1) * (CUmigration_f(lb))));
   //USA female removals at stage by USA fishery
   exploit_f1(lb,1) = c_f1(lb,1)*(1.0-propfor) / tmp_f1(lb,1);
   //CAN female removals at stage by USA fishery
   Cexploit_f1(lb,1) = Cexploit_f1(lb,1) + ((c_f1(lb,1)*propfor) / Ctmp_f1(lb,1));
   //USA female survival at stage after catch and natural mortality (half-year); cannot be zero, they still
exist
   sf1(1,lb) = posfun((1. - exploit_f1(lb,1)) * mfexp(-natmortf(lb)*0.5),eps,fpensf1(1));
   n_f1(lb,1) = log(tmp_f1(lb,1) * sf1(1,lb));
   N_f1(lb,1) = mfexp(n_f1(lb,1));
   //CAN female survival at stage after catch and natural mortality (half-year); cannot be zero, they still
exist
   Csf1(1,lb) = posfun((1. - Cexploit_f1(lb,1)) * mfexp(-natmortf(lb)*0.5),eps,Cfpensf1(1));
   Cn_f1(lb,1) = log(Ctmp_f1(lb,1) * Csf1(1,lb));
   CN_f1(lb,1) = mfexp(Cn_f1(lb,1));
   }
    //season 2 (new recruits enter here at the start of the period)
    //season 2 (portions of USA component in CAN region, so USA first; note pup before migrating)
   //juvenile males remaining juveniles
   mstay = N_m1(1,1)*(1.0-usagrowthmat(1,2));
   //juvenile males becoming mature
   mmoveon = N_m1(1,1)*usagrowthmat(1,2);
   //juvenile females remaining juveniles
   fstay = N_f1(1,1)*(1.0-usagrowthmat(1,3));
   //juvenile females becoming mature
   fmoveon = N_f1(1,1)*usagrowthmat(1,3);
   Cmstay = CN_m1(1,1)*(1.0-cangrowthmat(1,2));
   Cmmoveon = CN_m1(1,1)*cangrowthmat(1,2);
   Cfstay = CN_f1(1,1)*(1.0-cangrowthmat(1,3));
   Cfmoveon = CN_f1(1,1)*cangrowthmat(1,3);
   tmp_m2(1,1) = mstay;
   tmp_m2(2,1) = N_m1(2,1)+mmoveon;
   tmp_f2(1,1) = fstay;
   tmp_f2(2,1) = N_f1(2,1)+fmoveon;
   Ctmp_m2(1,1) = Cmstay;
   Ctmp_m2(2,1) = CN_m1(2,1)+Cmmoveon;
   Ctmp_f2(1,1) = Cfstay;
   Ctmp_f2(2,1) = CN_f1(2,1)+Cfmoveon;
   //recruitment between seasons
    //pups derive from mature females that 1. lived to the end of the last season, and yes/no 2. become mature
at this point (sequence issue)
    //the mfexp(-pupm) represents an extra M in the first year
    //estrec(1) = N_f1(2,1) * pupfac(1) * mfexp(-pupm);
    estrec(1) = tmp_f2(2,1) * pups(1) * mfexp(-pupm);
    //recruitment 50:50 by sex
    tmp_m2(1,1)=tmp_m2(1,1)+(estrec(1) * 0.5);
    tmp_f2(1,1)=tmp_f2(1,1)+(estrec(1) * 0.5);
    //Cestrec(1) = CN_f1(2,1) * cpupfac(1) * mfexp(-pupm);
    Cestrec(1) = Ctmp_f2(2,1) * cpups(1) * mfexp(-pupm);
    //recruitment 50:50 by sex
    Ctmp_m2(1,1)=Ctmp_m2(1,1)+(Cestrec(1) * 0.5);
    Ctmp_f2(1,1)=Ctmp_f2(1,1)+(Cestrec(1) * 0.5);
  for (lb=1; lb<=2; lb++) {
    //USA component & fishery
   exploit_m2(lb,1) = c_m2(lb,1) / tmp_m2(lb,1);
   exploit_f2(lb,1) = c_f2(lb,1) / tmp_f2(lb,1);
    //Canadian component & fishery + USA component
   //proportion USA male migrants in CAN
   propfor = (tmp_m2(lb,1) * (UCmigration_m(lb)))/(Ctmp_m2(lb,1)+(tmp_m2(lb,1) * (UCmigration_m(lb))));
   //CAN male removals at stage by CAN fishery
   Cexploit_m2(lb,1) = Cc_m2(lb,1)*(1.0-propfor) / Ctmp_m2(lb,1);
   //USA male removals at stage by CAN fishery
   exploit_m2(lb,1) = exploit_m2(lb,1) + ((Cc_m2(lb,1)*propfor) / tmp_m2(lb,1));
   Csm2(1,lb) = posfun((1. - Cexploit_m2(lb,1)) * mfexp(-natmortm(lb)*0.5),eps,Cfpensm2(1));
   Cn_m2(lb,1) = log(Ctmp_m2(lb,1) * Csm2(1,lb));
   CN_m2(lb,1) = mfexp(Cn_m2(lb,1));
   sm2(1,lb) = posfun((1. - exploit_m2(lb,1)) * mfexp(-natmortm(lb)*0.5),eps,fpensm2(1));
   n_m2(lb,1) = log(tmp_m2(lb,1) * sm2(1,lb));
   N_m2(lb,1) = mfexp(n_m2(lb,1));

   //proportion USA female migrants in CAN
   propfor = (tmp_f2(lb,1) * (UCmigration_f(lb)))/(Ctmp_f2(lb,1)+(tmp_f2(lb,1) * (UCmigration_f(lb))));
   //CAN female removals at stage by CAN fishery
   Cexploit_f2(lb,1) = Cc_f2(lb,1)*(1.0-propfor) / Ctmp_f2(lb,1);
   //USA female removals at stage by CAN fishery
   exploit_f2(lb,1) = exploit_f2(lb,1) + ((Cc_f2(lb,1)*propfor) / tmp_f2(lb,1));
   Csf2(1,lb) = posfun((1. - Cexploit_f2(lb,1)) * mfexp(-natmortf(lb)*0.5),eps,Cfpensf2(1));
   Cn_f2(lb,1) = log(Ctmp_f2(lb,1) * Csf2(1,lb));
   CN_f2(lb,1) = mfexp(Cn_f2(lb,1));
   sf2(1,lb) = posfun((1. - exploit_f2(lb,1)) * mfexp(-natmortf(lb)*0.5),eps,fpensf2(1));
   n_f2(lb,1) = log(tmp_f2(lb,1) * sf2(1,lb));
   N_f2(lb,1) = mfexp(n_f2(lb,1));
    //Q-adjusted predictions end of season 1 to compare with survey obs
    //predictions also adjusted for migratory portions of survey obs
    //Canadian survey is almost halfway through season 2; may want to adjust
   //Floating Q
   if(lb==1) {
    Im_mUSA(lb,1) = (tmp_m2(lb,1) + ((CUmigration_m(lb)) * CN_m2(lb,1)))*(mfexp(USAlogq1_mj)*fUSAlogq_mj(1));
    Im_fUSA(lb,1) = (tmp_f2(lb,1) + ((CUmigration_f(lb)) * CN_f2(lb,1)))*(mfexp(USAlogq1_fj)*fUSAlogq_fj(1));
    Im_mCAN(lb,1) = (CN_m2(lb,1) + ((UCmigration_m(lb)) * tmp_m2(lb,1)))*(mfexp(CANlogqATC_mj)*fCANlogq_mj(1));
    Im_fCAN(lb,1) = (CN_f2(lb,1) + ((UCmigration_f(lb)) * tmp_f2(lb,1)))*(mfexp(CANlogqATC_fj)*fCANlogq_fj(1));
   }
   if(lb==2) {
    Im_mUSA(lb,1) = (tmp_m2(lb,1) + ((CUmigration_m(lb)) * CN_m2(lb,1)))*(mfexp(USAlogq1_ma)*fUSAlogq_ma(1));
```

```
     Im_fUSA(lb,1) = (tmp_f2(lb,1) + ((CUmigration_f(lb)) * CN_f2(lb,1)))*(mfexp(USAlogq1_fa)*fUSAlogq_fa(1));
     Im_mCAN(lb,1) = (CN_m2(lb,1) + ((UCmigration_m(lb)) * tmp_m2(lb,1)))*(mfexp(CANloggATC_ma)*fCANlogq_ma(1));
     Im_fCAN(lb,1) = (CN_f2(lb,1) + ((UCmigration_f(lb)) * tmp_f2(lb,1)))*(mfexp(CANloggATC_fa)*fCANlogq_fa(1));
    }
  }

  // for years (t) 1962-2010; first year not part of loop
  for (t=2; t<=92; t++) {
    //season 1
  if(t<35) {
   //estimated transition from juvenile to adult
   mstay = N_m2(1,t-1)*(1.0-usagrowthmat(t,2));
   //juvenile males becoming mature
   mmoveon = N_m2(1,t-1)*usagrowthmat(t,2);
   //juvenile females remaining juveniles
   fstay = N_f2(1,t-1)*(1.0-usagrowthmat(t,3));
   //juvenile females becoming mature
   fmoveon = N_f2(1,t-1)*usagrowthmat(t,3);
   Cmstay = CN_m2(1,t-1)*(1.0-cangrowthmat(t,2));
   Cmmoveon = CN_m2(1,t-1)*cangrowthmat(t,2);
   Cfstay = CN_f2(1,t-1)*(1.0-cangrowthmat(t,3));
   Cfmoveon = CN_f2(1,t-1)*cangrowthmat(t,3);
  }
  if(t>=35) {
   //estimated transition from juvenile to adult
   mstay = N_m2(1,t-1)*(1.0-thetavarusa(1,t));
   //juvenile males becoming mature
   mmoveon = N_m2(1,t-1)*thetavarusa(1,t);
   //juvenile females remaining juveniles
   fstay = N_f2(1,t-1)*(1.0-thetavarusa(2,t));
   //juvenile females becoming mature
   fmoveon = N_f2(1,t-1)*thetavarusa(2,t);
   Cmstay = CN_m2(1,t-1)*(1.0-thetavarcan(1,t));
   Cmmoveon = CN_m2(1,t-1)*thetavarcan(1,t);
   Cfstay = CN_f2(1,t-1)*(1.0-thetavarcan(2,t));
   Cfmoveon = CN_f2(1,t-1)*thetavarcan(2,t);
  }
   //theta
   Ctmp_m1(1,t) = Cmstay;
   Ctmp_m1(2,t) = CN_m2(2,t-1)+Cmmoveon;
   Ctmp_f1(1,t) = Cfstay;
   Ctmp_f1(2,t) = CN_f2(2,t-1)+Cfmoveon;
   tmp_m1(1,t) = mstay;
   tmp_m1(2,t) = N_m2(2,t-1)+mmoveon;
   tmp_f1(1,t) = fstay;
   tmp_f1(2,t) = N_f2(2,t-1)+fmoveon;
  for (lb=1; lb<=2; lb++) {
    //CAN component & fishery
   //CAN male removals at stage by CAN fishery
   Cexploit_m1(lb,t) = Cc_m1(lb,t) / Ctmp_m1(lb,t);
   //females
   Cexploit_f1(lb,t) = Cc_f1(lb,t) / Ctmp_f1(lb,t);
    //USA component & fishery + CAN component
   //proportion CAN male migrants in USA
   if(t<47) propfor = (Ctmp_m1(lb,t) * (CUmigration_m(lb)))/(tmp_m1(lb,t)+(Ctmp_m1(lb,t) *
(CUmigration_m(lb))));
   if(t>=47) propfor = (Ctmp_m1(lb,t) *
(CUmigration_m(lb)*varCUmigration_m(lb,t)))/(tmp_m1(lb,t)+(Ctmp_m1(lb,t) *
(CUmigration_m(lb)*varCUmigration_m(lb,t))));
   //USA male removals at stage by USA fishery
   exploit_m1(lb,t) = c_m1(lb,t)*(1.0-propfor) / tmp_m1(lb,t);
   //CAN male removals at stage by USA fishery
   Cexploit_m1(lb,t) = Cexploit_m1(lb,t) + ((c_m1(lb,t)*propfor) / Ctmp_m1(lb,t));
   //USA male survival at stage after catch and natural mortality (half-year); cannot be zero, they still exist
   sm1(t,lb) = posfun((1. - exploit_m1(lb,t)) * mfexp(-natmortm(lb)*0.5),eps,fpensm1(t));
   n_m1(lb,t) = log(tmp_m1(lb,t) * sm1(t,lb));
   N_m1(lb,t) = mfexp(n_m1(lb,t));
   //CAN male survival at stage after catch and natural mortality (half-year); cannot be zero, they still exist
   Csm1(t,lb) = posfun((1. - Cexploit_m1(lb,t)) * mfexp(-natmortm(lb)*0.5),eps,Cfpensm1(t));
   Cn_m1(lb,t) = log(Ctmp_m1(lb,t) * Csm1(t,lb));
   CN_m1(lb,t) = mfexp(Cn_m1(lb,t));
   //females
   //proportion CAN female migrants in USA
   if(t<47) propfor = (Ctmp_f1(lb,t) * (CUmigration_f(lb)))/(tmp_f1(lb,t)+(Ctmp_f1(lb,t) *
(CUmigration_f(lb))));
   if(t>=47) propfor = (Ctmp_f1(lb,t) *
(CUmigration_f(lb)*varCUmigration_f(lb,t)))/(tmp_f1(lb,t)+(Ctmp_f1(lb,t) *
(CUmigration_f(lb)*varCUmigration_f(lb,t))));
   //USA female removals at stage by USA fishery
   exploit_f1(lb,t) = c_f1(lb,t)*(1.0-propfor) / tmp_f1(lb,t);
   //CAN female removals at stage by USA fishery
   Cexploit_f1(lb,t) = Cexploit_f1(lb,t) + ((c_f1(lb,t)*propfor) / Ctmp_f1(lb,t));
   //USA female survival at stage after catch and natural mortality (half-year); cannot be zero, they still
exist
```

```
    sf1(t,lb) = posfun((1. - exploit_f1(lb,t)) * mfexp(-natmortf(lb)*0.5),eps,fpensf1(t));
    n_f1(lb,t) = log(tmp_f1(lb,t) * sf1(t,lb));
    N_f1(lb,t) = mfexp(n_f1(lb,t));
    //CAN female survival at stage after catch and natural mortality (half-year); cannot be zero, they still
exist
    Csf1(t,lb) = posfun((1. - Cexploit_f1(lb,t)) * mfexp(-natmortf(lb)*0.5),eps,Cfpensf1(t));
    Cn_f1(lb,t) = log(Ctmp_f1(lb,t) * Csf1(t,lb));
    CN_f1(lb,t) = mfexp(Cn_f1(lb,t));
    }
     //season 2 (new recruits enter here at the start of the period)
     //season 2 (portions of USA component in CAN region, so USA first; note pup before migrating)
   if(t<35) {
    //estimated transition from juvenile to adult
    mstay = N_m1(1,t)*(1.0-usagrowthmat(t,2));
    //juvenile males becoming mature
    mmoveon = N_m1(1,t)*usagrowthmat(t,2);
    //juvenile females remaining juveniles
    fstay = N_f1(1,t)*(1.0-usagrowthmat(t,3));
    //juvenile females becoming mature
    fmoveon = N_f1(1,t)*usagrowthmat(t,3);
    Cmstay = CN_m1(1,t)*(1.0-cangrowthmat(t,2));
    Cmmoveon = CN_m1(1,t)*cangrowthmat(t,2);
    Cfstay = CN_f1(1,t)*(1.0-cangrowthmat(t,3));
    Cfmoveon = CN_f1(1,t)*cangrowtbmat(t,3);
   }
   if(t>=35) {
    //estimated transition from juvenile to adult
    mstay = N_m1(1,t)*(1.0-thetavarusa(1,t));
    //juvenile males becoming mature
    mmoveon = N_m1(1,t)*thetavarusa(1,t);
    //juvenile females remaining juveniles
    fstay = N_f1(1,t)*(1.0-thetavarusa(2,t));
    //juvenile females becoming mature
    fmoveon = N_f1(1,t)*thetavarusa(2,t);
    Cmstay = CN_m1(1,t)*(1.0-thetavarcan(1,t));
    Cmmoveon = CN_m1(1,t)*thetavarcan(1,t);
    Cfstay = CN_f1(1,t)*(1.0-thetavarcan(2,t));
    Cfmoveon = CN_f1(1,t)*thetavarcan(2,t);
   }
    tmp_m2(1,t) = mstay;
    tmp_m2(2,t) = N_m1(2,t)+mmoveon;
    tmp_f2(1,t) = fstay;
    tmp_f2(2,t) = N_f1(2,t)+fmoveon;
    Ctmp_m2(1,t) = Cmstay;
    Ctmp_m2(2,t) = CN_m1(2,t)+Cmmoveon;
    Ctmp_f2(1,t) = Cfstay;
    Ctmp_f2(2,t) = CN_f1(2,t)+Cfmoveon;
     //using N_f1(2,t) derives pups from the mature survivors of last season
     //using tmp_2(2,t) derives pups from the mature survivors of last season plus the new matures
     //estrec(t) = N_f1(2,t) * pupfac(t) * mfexp(-pupm);
   if(t<35) {
     estrec(t) = tmp_f2(2,t) * pups(t) * mfexp(-pupm);
     Cestrec(t) = Ctmp_f2(2,t) * cpups(t) * mfexp(-pupm);
   }
   if(t>=35) {
     estrec(t) = tmp_f2(2,t) * pupfac(t) * mfexp(-pupm);
     //Cestrec(t) = CN_f1(2,t) *  cpupfac(t) * mfexp(-pupm);
     Cestrec(t) = Ctmp_f2(2,t) * cpupfac(t) * mfexp(-pupm);
   }
     //recruitment 50:50 by sex
     Ctmp_m2(1,t)=Ctmp_m2(1,t)+(Cestrec(t) * 0.5);
     Ctmp_f2(1,t)=Ctmp_f2(1,t)+(Cestrec(t) * 0.5);
     //recruitment 50:50 by sex
     tmp_m2(1,t)=tmp_m2(1,t)+(estrec(t) * 0.5);
     tmp_f2(1,t)=tmp_f2(1,t)+(estrec(t) * 0.5);
   for (lb=1; lb<=2; lb++) {
     //USA component & fishery
    exploit_m2(lb,t) = c_m2(lb,t) / tmp_m2(lb,t);
    exploit_f2(lb,t) = c_f2(lb,t) / tmp_f2(lb,t);
     //Canadian component & fishery + USA component
    //proportion USA male migrants in CAN
    if(t<47) propfor = (tmp_m2(lb,t) * (UCmigration_m(lb)))/(Ctmp_m2(lb,t)+(tmp_m2(lb,t) *
(UCmigration_m(lb))));
    if(t>=47) propfor = (tmp_m2(lb,t) * (UCmigration_m(lb)*varUCmigration_m(lb,t)))/(Ctmp_m2(lb,t)+(tmp_m2(lb,t)
* (UCmigration_m(lb)*varUCmigration_m(lb,t))));
    //CAN male removals at stage by CAN fishery
    Cexploit_m2(lb,t) = Cc_m2(lb,t)*(1.0-propfor) / Ctmp_m2(lb,t);
    //USA male removals at stage by CAN fishery
    exploit_m2(lb,t) = exploit_m2(lb,t) + ((Cc_m2(lb,t)*propfor) / tmp_m2(lb,t));
    Csm2(t,lb) = posfun((1. - Cexploit_m2(lb,t)) * mfexp(-natmortm(lb)*0.5),eps,Cfpensm2(t));
    Cn_m2(lb,t) = log(Ctmp_m2(lb,t) * Csm2(t,lb));
    CN_m2(lb,t) = mfexp(Cn_m2(lb,t));
    sm2(t,lb) = posfun((1. - exploit_m2(lb,t)) * mfexp(-natmortm(lb)*0.5),eps,fpensm2(t));
    n_m2(lb,t) = log(tmp_m2(lb,t) * sm2(t,lb));
   N_m2(lb,t) = mfexp(n_m2(lb,t));

   //proportion USA female migrants in CAN
   if(t<47) propfor = (tmp_f2(lb,t) * (UCmigration_f(lb)))/(Ctmp_f2(lb,t)+(tmp_f2(lb,t) *
(UCmigration_f(lb))));
   if(t>=47) propfor = (tmp_f2(lb,t) * (UCmigration_f(lb)*varUCmigration_f(lb,t)))/(Ctmp_f2(lb,t)+(tmp_f2(lb,t)
* (UCmigration_f(lb)*varUCmigration_f(lb,t))));
   //CAN female removals at stage by CAN fishery
   Cexploit_f2(lb,t) = Cc_f2(lb,t)*(1.0-propfor) / Ctmp_f2(lb,t);
   //USA female removals at stage by CAN fishery
   exploit_f2(lb,t) = exploit_f2(lb,t) + ((Cc_f2(lb,t)*propfor) / tmp_f2(lb,t));
   Csf2(t,lb) = posfun((1. - Cexploit_f2(lb,t)) * mfexp(-natmortf(lb)*0.5),eps,Cfpensf2(t));
   Cn_f2(lb,t) = log(Ctmp_f2(lb,t) * Csf2(t,lb));
   CN_f2(lb,t) = mfexp(Cn_f2(Ib,t));
   sf2(t,lb) = posfun((1. - exploit_f2(lb,t)) * mfexp(-natmortf(lb)*0.5),eps,fpensf2(t));
   n_f2(lb,t) = log(tmp_f2(lb,t) * sf2(t,lb));
   N_f2(lb,t) = mfexp(n_f2(lb,t));
    //Q-adjusted predictions end of season 1 to compare with survey obs
    //Canadian survey is almost halfway through season 2; may want to adjust
   //Floating Q
    if(t>=2 & t<=46) {
   if(lb==1) {
    Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)) * CN_m2(lb,t)))*(mfexp(USAlogq1_mj)*fUSAlogq_mj(t));
    Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)) * CN_f2(lb,t)))*(mfexp(USAlogq1_fj)*fUSAlogq_fj(t));
    Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)) * tmp_m2(lb,t)))*(mfexp(CANlogqATC_mj)*fCANlogq_mj(t));
    Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)) * tmp_f2(lb,t)))*(mfexp(CANlogqATC_fj)*fCANlogq_fj(t));
   }
   if(lb==2) {
    Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)) * CN_m2(lb,t)))*(mfexp(USAlogq1_ma)*fUSAlogq_ma(t));
    Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)) * CN_f2(lb,t)))*(mfexp(USAlogq1_fa)*fUSAlogq_fa(t));
    Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)) * tmp_m2(lb,t)))*(mfexp(CANlogqATC_ma)*fCANlogq_ma(t));
    Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)) * tmp_f2(lb,t)))*(mfexp(CANlogqATC_fa)*fCANlogq_fa(t));
   }
   }
    if(t>=47 & t<=60) {
   if(lb==1) {
    Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq1_mj)*fUSAlogq_mj(t));
    Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq1_fj)*fUSAlogq_fj(t));
    Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogqATC_mj)*fCANlogq_mj(t));
    Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogqATC_fj)*fCANlogq_fj(t));
   }
   if(lb==2) {
    Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq1_ma)*fUSAlogq_ma(t));
    Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq1_fa)*fUSAlogq_fa(t));
    Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogqATC_ma)*fCANlogq_ma(t));
    Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogqATC_fa)*fCANlogq_fa(t));
   }
   }
    if(t>=61 & t<=66) {
   if(lb==1) {
    Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq1_mj)*fUSAlogq_mj(t));
    Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq1_fj)*fUSAlogq_fj(t));
    Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_mj)*fCANlogq_mj(t));
    Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fj)*fCANlogq_fj(t));
   }
   if(lb==2) {
    Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq1_ma)*fUSAlogq_ma(t));
    Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq1_fa)*fUSAlogq_fa(t));
    Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_ma)*fCANlogq_ma(t));
    Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fa)*fCANlogq_fa(t));
   }
   }
    if(t>=67 & t<=78) {
   if(lb==1) {
    Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq2_mj)*fUSAlogq_mj(t));
    Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq2_fj)*fUSAlogq_fj(t));
```

```
      Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_mj)*fCANlogq_mj(t));
      Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fj)*fCANlogq_fj(t));
    }
    if(lb==2) {
      Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq2_ma)*fUSAlogq_ma(t));
      Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq2_fa)*fUSAlogq_fa(t));
      Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_ma)*fCANlogq_ma(t));
      Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fa)*fCANlogq_fa(t));
    }
    }
    if(t>=79 & t<=81) {
    if(lb==1) {
      Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq3_mj)*fUSAlogq_mj(t));
      Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq3_fj)*fUSAlogq_fj(t));
      Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_mj)*fCANlogq_mj(t));
      Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fj)*fCANlogq_fj(t));
    }
    if(lb==2) {
      Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq3_ma)*fUSAlogq_ma(t));
      Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq3_fa)*fUSAlogq_fa(t));
      Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_ma)*fCANlogq_ma(t));
      Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fa)*fCANlogq_fa(t));
    }
    }
    if(t>=82 & t<=87) {
    if(lb==1) {
      Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq2_mj)*fUSAlogq_mj(t));
      Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq2_fj)*fUSAlogq_fj(t));
      Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_mj)*fCANlogq_mj(t));
      Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fj)*fCANlogq_fj(t));
    }
    if(lb==2) {
      Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq2_ma)*fUSAlogq_ma(t));
      Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq2_fa)*fUSAlogq_fa(t));
      Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_ma)*fCANlogq_ma(t));
      Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fa)*fCANlogq_fa(t));
    }
    }
    if(t>=88) {
    if(lb==1) {
      Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq4_mj)*fUSAlogq_mj(t));
      Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq4_fj)*fUSAlogq_fj(t));
      Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_mj)*fCANlogq_mj(t));
      Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fj)*fCANlogq_fj(t));
    }
    if(lb==2) {
      Im_mUSA(lb,t) = (tmp_m2(lb,t) + ((CUmigration_m(lb)*varCUmigration_m(lb,t)) *
CN_m2(lb,t)))*(mfexp(USAlogq4_ma)*fUSAlogq_ma(t));
      Im_fUSA(lb,t) = (tmp_f2(lb,t) + ((CUmigration_f(lb)*varCUmigration_f(lb,t)) *
CN_f2(lb,t)))*(mfexp(USAlogq4_fa)*fUSAlogq_fa(t));
      Im_mCAN(lb,t) = (CN_m2(lb,t) + ((UCmigration_m(lb)*varUCmigration_m(lb,t)) *
tmp_m2(lb,t)))*(mfexp(CANlogq_ma)*fCANlogq_ma(t));
      Im_fCAN(lb,t) = (CN_f2(lb,t) + ((UCmigration_f(lb)*varUCmigration_f(lb,t)) *
tmp_f2(lb,t)))*(mfexp(CANlogq_fa)*fCANlogq_fa(t));
    }
   }
   }
   }
```

```
  //Compose sex/stage population components for fitting (and season for catch)
for (int ys=1; ys<=92; ys++) {
  USAMJ(ys)=Im_mUSA(1,ys);
  USAMA(ys)=Im_mUSA(2,ys);
  USAFJ(ys)=Im_fUSA(1,ys);
  USAFA(ys)=Im_fUSA(2,ys);
  CANMJ(ys)=Im_mCAN(1,ys);
  CANMA(ys)=Im_mCAN(2,ys);
  CANFJ(ys)=Im_fCAN(1,ys);
  CANFA(ys)=Im_fCAN(2,ys);
  PredCatchUSAMJ1(ys)=c_m1(1,ys);
  PredCatchUSAMA1(ys)=c_m1(2,ys);
  PredCatchUSAFJ1(ys)=c_f1(1,ys);
  PredCatchUSAFA1(ys)=c_f1(2,ys);
  PredCatchUSAMJ2(ys)=c_m2(1,ys);
  PredCatchUSAMA2(ys)=c_m2(2,ys);
  PredCatchUSAFJ2(ys)=c_f2(1,ys);
  PredCatchUSAFA2(ys)=c_f2(2,ys);
  PredCatchCANMJ1(ys)=Cc_m1(1,ys);
  PredCatchCANMA1(ys)=Cc_m1(2,ys);
  PredCatchCANFJ1(ys)=Cc_f1(1,ys);
  PredCatchCANFA1(ys)=Cc_f1(2,ys);
  PredCatchCANMJ2(ys)=Cc_m2(1,ys);
  PredCatchCANMA2(ys)=Cc_m2(2,ys);
  PredCatchCANFJ2(ys)=Cc_f2(1,ys);
  PredCatchCANFA2(ys)=Cc_f2(2,ys);
vCsm1(ys,1)=Csm1(ys,1);  //Canadian male survival rate from fishing season 1
vCsf1(ys,1)=Csf1(ys,1);  //Canadian female survival rate from fishing season 1
vCsm2(ys,1)=Csm2(ys,1);  //Canadian male survival rate from fishing season 2
vCsf2(ys,1)=Csf2(ys,1);  //Canadian female survival rate from fishing season 2
vsm1(ys,1)=sm1(ys,1);  //US male survival rate from fishing season 1
vsf1(ys,1)=sf1(ys,1);  //US female survival rate from fishing season 1
vsm2(ys,1)=sm2(ys,1);  //US male survival rate from fishing season 2
vsf2(ys,1)=sf2(ys,1);  //US female survival rate from fishing season 2
vCsm1(ys,2)=Csm1(ys,2);  //Canadian male survival rate from fishing season 1
vCsf1(ys,2)=Csf1(ys,2);  //Canadian female survival rate from fishing season 1
vCsm2(ys,2)=Csm2(ys,2);  //Canadian male survival rate from fishing season 2
vCsf2(ys,2)=Csf2(ys,2);  //Canadian female survival rate from fishing season 2
vsm1(ys,2)=sm1(ys,2);  //US male survival rate from fishing season 1
vsf1(ys,2)=sf1(ys,2);  //US female survival rate from fishing season 1
vsm2(ys,2)=sm2(ys,2);  //US male survival rate from fishing season 2
vsf2(ys,2)=sf2(ys,2);  //US female survival rate from fishing season 2
}
//projections
//USA
//deterministic region-specific theta (these are constants)
//deterministic region-specific pupping as calculated in last observed year
//US 50:50 split by season;
//US TAC =16103mt;
//Catch=16103 mt
//Catch=landings of 16103 mt + 2010 discards (13895 mt)= 16103+13895 = 29998 mt
//Catch=landings of 16103 mt + 2010 proportion of discards (23004 mt) = 16103+23004 = 39107 mt
//catch comp=mj .164, ma, .206, fj .282, fa .348
//fish per ton = 362
//362*16103
//362*29998
//362*39107
//Canada
//deterministic region-specific theta (these are constants)
//deterministic USA pupping as calculated in last observed year
//CAN catch=1500,2000,2500,3000,3500; this includes discards
//CAN .07 season 1,.93 season 2
//catch comp=mj .04, ma, .24, fj .42, fa .30
//fish per ton = 381
int projection=1;
int simulation=0;
//dead discards using original assumption of discards proportional to landings
//dvariable USATAC=362*45081;
//dead discards using US FMP assumption would be 5307*362; TAL=18960*362
//dvariable USATAC=362*(18960+5307);
dvariable CANTAC=0;
dvariable USATAC=0;
//population model,catch ratio method, total abundance (sustainability)
//50%
//USATAC=(362*47350*.84);
//CANTAC=(381*47350*.16);
//25%
//USATAC=(362*45000*.84);
//CANTAC=(381*45000*.16);
//75%
//USATAC=(362*48500*.84);
//CANTAC=(381*48500*.16);
//population model,catch ratio method, SSN (MSY)
```

```
//50%
//USATAC=(362*25000*.84);
//CANTAC=(381*25000*.16);
//75%
//USATAC=(362*45000*.84);
//CANTAC=(381*45000*.16);
//25%
USATAC=(362*7000*.84);
CANTAC=(381*7000*.16);
//25%
//USATAC=(362*7000*.84);
//CANTAC=(381*7000*.16);
//population model,K ratio method, total abundance (sustainability) probabilities
//50%
//USATAC=(362*49100*.59);
//CANTAC=(381*49100*.41);
//25%
//USATAC=(362*47000*.59);
//CANTAC=(381*47000*.41);
//75%
//USATAC=(362*50500*.59);
//CANTAC=(381*50500*.41);
//population model,K ratio method, SSN (MSY) probabilities
//75%
//USATAC=(362*42000*.59);
//CANTAC=(381*42000*.41);
//50%
//USATAC=(362*27000*.59);
//CANTAC=(381*27000*.41);
//25%
//USATAC=(362*7000*.59);
//CANTAC=(381*7000*.41);
//population model,US 2014 TAC plus Canadian catch from catch ratio method, straight projection
//USATAC=362*24176;
//CANTAC=381*1894;
//population model,US 2014 TAC plus Canadian catch from K ratio method, straight projection
USATAC=362*24176;
CANTAC=381*5033;
for (t=93; t<=192; t++) {
//
Cc_m1(1,t) = CANTAC*.07*.04;
Cc_m1(2,t) = CANTAC*.07*.24;
Cc_f1(1,t) = CANTAC*.07*.42;
Cc_f1(2,t) = CANTAC*.07*.30;
Cc_m2(1,t) = CANTAC*.93*.04;
Cc_m2(2,t) = CANTAC*.93*.24;
Cc_f2(1,t) = CANTAC*.93*.42;
Cc_f2(2,t) = CANTAC*.93*.30;
c_m1(1,t) = USATAC*.5*.164;
c_m1(2,t) = USATAC*.5*.206;
c_f1(1,t) = USATAC*.5*.282;
c_f1(2,t) = USATAC*.5*.348;
c_m2(1,t) = USATAC*.5*.164;
c_m2(2,t) = USATAC*.5*.206;
c_f2(1,t) = USATAC*.5*.282;
c_f2(2,t) = USATAC*.5*.348;
//
//subbing Canadian catch proportions from 2002 (highest adult female catch)
/*
Cc_m1(1,t) = CANTAC*.07*.02383457;
Cc_m1(2,t) = CANTAC*.07*.16821183;
Cc_f1(1,t) = CANTAC*.07*.3821215;
Cc_f1(2,t) = CANTAC*.07*.4258321;
Cc_m2(1,t) = CANTAC*.93*.02383457;
Cc_m2(2,t) = CANTAC*.93*.16821183;
Cc_f2(1,t) = CANTAC*.93*.3821215;
Cc_f2(2,t) = CANTAC*.93*.4258321;
*/
//subbing US catch proportions from 2007 (highest adult female catch)
/*
c_m1(1,t) = USATAC*.5*.069;
c_m1(2,t) = USATAC*.5*.263;
c_f1(1,t) = USATAC*.5*.239;
c_f1(2,t) = USATAC*.5*.429;
c_m2(1,t) = USATAC*.5*.069;
c_m2(2,t) = USATAC*.5*.263;
c_f2(1,t) = USATAC*.5*.239;
c_f2(2,t) = USATAC*.5*.429;
*/
//cout<<t<<" c_f2(2,t) "<<c_f2(2,t)<<endl;
}

//Projections
//if(current_phase()==lastphase) {
  for (t=93; t<=192; t++) {
    //season 1
   /*
   //using estimated theta values of last observed year
   //estimated transition from juvenile to adult
   mstay = N_m2(1,t-1)*(1.0-thetavarusa(1,nobs));
   //juvenile males becoming mature
   mmoveon = N_m2(1,t-1)*thetavarusa(1,nobs);
   //juvenile females remaining juveniles
   fstay = N_f2(1,t-1)*(1.0-thetavarusa(2,nobs));
   //juvenile females becoming mature
   fmoveon = N_f2(1,t-1)*thetavarusa(2,nobs);
   Cmstay = CN_m2(1,t-1)*(1.0-thetavarcan(1,nobs));
   Cmmoveon = CN_m2(1,t-1)*thetavarcan(1,nobs);
   Cfstay = CN_f2(1,t-1)*(1.0-thetavarcan(2,nobs));
   Cfmoveon = CN_f2(1,t-1)*thetavarcan(2,nobs);
   */
   //using deterministic theta values of last observed year
   //estimated transition from juvenile to adult
   mstay = N_m2(1,t-1)*(1.0-usagrowthmat(nobs,2));
   //juvenile males becoming mature
   mmoveon = N_m2(1,t-1)*usagrowthmat(nobs,2);
   //juvenile females remaining juveniles
   fstay = N_f2(1,t-1)*(1.0-usagrowthmat(nobs,3));
   //juvenile females becoming mature
   fmoveon = N_f2(1,t-1)*usagrowthmat(nobs,3);
   Cmstay = CN_m2(1,t-1)*(1.0-cangrowthmat(nobs,2));
   Cmmoveon = CN_m2(1,t-1)*cangrowthmat(nobs,2);
   Cfstay = CN_f2(1,t-1)*(1.0-cangrowthmat(nobs,3));
   Cfmoveon = CN_f2(1,t-1)*cangrowthmat(nobs,3);
   Ctmp_m1(1,t) = Cmstay;
   Ctmp_m1(2,t) = CN_m2(2,t-1)+Cmmoveon;
   Ctmp_f1(1,t) = Cfstay;
   Ctmp_f1(2,t) = CN_f2(2,t-1)+Cfmoveon;
   tmp_m1(1,t) = mstay;
   tmp_m1(2,t) = N_m2(2,t-1)+mmoveon;
   tmp_f1(1,t) = fstay;
   tmp_f1(2,t) = N_f2(2,t-1)+fmoveon;
  for (lb=1; lb<=2; lb++) {
    //CAN component & fishery
   //CAN male removals at stage by CAN fishery
   Cexploit_m1(lb,t) = Cc_m1(lb,t) / Ctmp_m1(lb,t);
   //females
   Cexploit_f1(lb,t) = Cc_f1(lb,t) / Ctmp_f1(lb,t);
    //USA component & fishery + CAN component
   //proportion CAN male migrants in USA
   propfor = (Ctmp_m1(lb,t) * (CUmigration_m(lb)))/(tmp_m1(lb,t)+(Ctmp_m1(lb,t) * (CUmigration_m(lb))));
   //USA male removals at stage by USA fishery
   //do not let the catch exceed the abundance (when including migrants)
   c_m1(lb,t)=min(value(c_m1(lb,t)),value(tmp_m1(lb,t) + (Ctmp_m1(lb,t)*CUmigration_m(lb))));
   exploit_m1(lb,t) = c_m1(lb,t)*(1.0-propfor) / tmp_m1(lb,t);
   //CAN male removals at stage by USA fishery
   Cexploit_m1(lb,t) = Cexploit_m1(lb,t) + ((c_m1(lb,t)*propfor) / Ctmp_m1(lb,t));
   //USA male survival at stage after catch and natural mortality (half-year); cannot be zero, they still exist
   //cout<<t<<" before "<<endl;
   sm1(t,lb) = posfun((1. - exploit_m1(lb,t)) * mfexp(-natmortm(lb)*0.5),eps,projfpensm1(t));
   //cout<<" after "<<endl;
   n_m1(lb,t) = log(tmp_m1(lb,t) * sm1(t,lb));
   N_m1(lb,t) = mfexp(n_m1(lb,t));
   //CAN male survival at stage after catch and natural mortality (half-year); cannot be zero, they still exist
   Csm1(t,lb) = posfun((1. - Cexploit_m1(lb,t)) * mfexp(-natmortm(lb)*0.5),eps,projCfpensm1(t));
   Cn_m1(lb,t) = log(Ctmp_m1(lb,t) * Csm1(t,lb));
   CN_m1(lb,t) = mfexp(Cn_m1(lb,t));
   //females
   //proportion CAN female migrants in USA
   propfor = (Ctmp_f1(lb,t) * (CUmigration_f(lb)))/(tmp_f1(lb,t)+(Ctmp_f1(lb,t) * (CUmigration_f(lb))));
   //
   //if(current_phase()==lastphase) {
   //cout<<t<<" "<<lb<<" female season 1 propfor "<<propfor<<" applied "<<((c_f1(lb,t)*propfor) /
Ctmp_f1(lb,t))<<endl;
   //}
   //
   //USA female removals at stage by USA fishery
   //do not let the catch exceed the abundance (when including migrants)
   c_f1(lb,t)=min(value(c_f1(lb,t)),value(tmp_f1(lb,t) + (Ctmp_f1(lb,t)*CUmigration_f(lb))));
   exploit_f1(lb,t) = c_f1(lb,t)*(1.0-propfor) / tmp_f1(lb,t);
   //CAN female removals at stage by USA fishery
   Cexploit_f1(lb,t) = Cexploit_f1(lb,t) + ((c_f1(lb,t)*propfor) / Ctmp_f1(lb,t));
   //USA female survival at stage after catch and natural mortality (half-year); cannot be zero, they still
exist
   sf1(t,lb) = posfun((1. - exploit_f1(lb,t)) * mfexp(-natmortf(lb)*0.5),eps,projfpensf1(t));
   n_f1(lb,t) = log(tmp_f1(lb,t) * sf1(t,lb));
   N_f1(lb,t) = mfexp(n_f1(lb,t));
   //CAN female survival at stage after catch and natural mortality (half-year); cannot be zero, they still
exist
   Csf1(t,lb) = posfun((1. - Cexploit_f1(lb,t)) * mfexp(-natmortf(lb)*0.5),eps,projCfpensf1(t));
   Cn_f1(lb,t) = log(Ctmp_f1(lb,t) * Csf1(t,lb));
   CN_f1(lb,t) = mfexp(Cn_f1(lb,t));
   }
    //season 2 (new recruits enter here at the start of the period)
    //season 2 (portions of USA component in CAN region, so USA first; note pup before migrating)
   /*
   //estimated transition from juvenile to adult
   mstay = N_m1(1,t)*(1.0-thetavarusa(1,nobs));
   //juvenile males becoming mature
   mmoveon = N_m1(1,t)*thetavarusa(1,nobs);
   //juvenile females remaining juveniles
   fstay = N_f1(1,t)*(1.0-thetavarusa(2,nobs));
   //juvenile females becoming mature
   fmoveon = N_f1(1,t)*thetavarusa(2,nobs);
   Cmstay = CN_m1(1,t)*(1.0-thetavarcan(1,nobs));
   Cmmoveon = CN_m1(1,t)*thetavarcan(1,nobs);
   Cfstay = CN_f1(1,t)*(1.0-thetavarcan(2,nobs));
   Cfmoveon = CN_f1(1,t)*thetavarcan(2,nobs);
   */
   //estimated transition from juvenile to adult
   mstay = N_m1(1,t)*(1.0-usagrowthmat(nobs,2));
   //juvenile males becoming mature
   mmoveon = N_m1(1,t)*usagrowthmat(nobs,2);
   //juvenile females remaining juveniles
   fstay = N_f1(1,t)*(1.0-usagrowthmat(nobs,3));
   //juvenile females becoming mature
   fmoveon = N_f1(1,t)*usagrowthmat(nobs,3);
   Cmstay = CN_m1(1,t)*(1.0-cangrowthmat(nobs,2));
   Cmmoveon = CN_m1(1,t)*cangrowthmat(nobs,2);
   Cfstay = CN_f1(1,t)*(1.0-cangrowthmat(nobs,3));
   Cfmoveon = CN_f1(1,t)*cangrowthmat(nobs,3);
   tmp_m2(1,t) = mstay;
   tmp_m2(2,t) = N_m1(2,t)+mmoveon;
   tmp_f2(1,t) = fstay;
   tmp_f2(2,t) = N_f1(2,t)+fmoveon;
   Ctmp_m2(1,t) = Cmstay;
   Ctmp_m2(2,t) = CN_m1(2,t)+Cmmoveon;
   Ctmp_f2(1,t) = Cfstay;
   Ctmp_f2(2,t) = CN_f1(2,t)+Cfmoveon;
    //using N_f1(2,t) derives pups from the mature survivors of last season
    //using tmp_2(2,t) derives pups from the mature survivors of last season plus the new matures
    //estrec(t) = N_f1(2,t) * pupfac(t) * mfexp(-pupm);
    //for short-term projections using pupping factor of last observed year
    //for long-term projections using deterministic pupping factor
  if(simulation=1) {
    estrec(t) = tmp_f2(2,t) * pups(1) * mfexp(-pupm);
    Cestrec(t) = Ctmp_f2(2,t) * cpups(1) * mfexp(-pupm);
  }
  if(projection=1) {
    //Using estimated pupping in last observed year
    //estrec(t) = tmp_f2(2,t) * pupfac(nobs) * mfexp(-pupm);
    //Cestrec(t) = Ctmp_f2(2,t) * cpupfac(nobs) * mfexp(-pupm);
    //Using deterministic pupping in last observed year
    estrec(t) = tmp_f2(2,t) * pups(nobs) * mfexp(-pupm);
    Cestrec(t) = Ctmp_f2(2,t) * cpups(nobs) * mfexp(-pupm);
  }
    //recruitment 50:50 by sex
    Ctmp_m2(1,t)=Ctmp_m2(1,t)+(Cestrec(t) * 0.5);
    Ctmp_f2(1,t)=Ctmp_f2(1,t)+(Cestrec(t) * 0.5);
    //recruitment 50:50 by sex
    tmp_m2(1,t)=tmp_m2(1,t)+(estrec(t) * 0.5);
    tmp_f2(1,t)=tmp_f2(1,t)+(estrec(t) * 0.5);
  for (lb=1; lb<=2; lb++) {
    //USA component & fishery
   exploit_m2(lb,t) = c_m2(lb,t) / tmp_m2(lb,t);
   exploit_f2(lb,t) = c_f2(lb,t) / tmp_f2(lb,t);
    //Canadian component & fishery + USA component
   //proportion USA male migrants in CAN
   propfor = (tmp_m2(lb,t) * (UCmigration_m(lb)))/(Ctmp_m2(lb,t)+(tmp_m2(lb,t) * (UCmigration_m(lb))));
   //CAN male removals at stage by CAN fishery
   Cexploit_m2(lb,t) = Cc_m2(lb,t)*(1.0-propfor) / Ctmp_m2(lb,t);
   //USA male removals at stage by CAN fishery
   //do not let the catch exceed the abundance (when including migrants)
   Cc_m2(lb,t)=min(value(Cc_m2(lb,t)),value(Ctmp_m2(lb,t) + (tmp_m2(lb,t)*UCmigration_m(lb))));
   exploit_m2(lb,t) = exploit_m2(lb,t) + ((Cc_m2(lb,t)*propfor) / tmp_m2(lb,t));
   Csm2(t,lb) = posfun((1. - Cexploit_m2(lb,t)) * mfexp(-natmortm(lb)*0.5),eps,projCfpensm2(t));
   Cn_m2(lb,t) = log(Ctmp_m2(lb,t) * Csm2(t,lb));
   CN_m2(lb,t) = mfexp(Cn_m2(lb,t));
   sm2(t,lb) = posfun((1. - exploit_m2(lb,t)) * mfexp(-natmortm(lb)*0.5),eps,projfpensm2(t));
   n_m2(lb,t) = log(tmp_m2(lb,t) * sm2(t,lb));
   N_m2(lb,t) = mfexp(n_m2(lb,t));
```

```
    //proportion USA female migrants in CAN
    propfor = (tmp_f2(lb,t) * (UCmigration_f(lb)))/(Ctmp_f2(lb,t)+(tmp_f2(lb,t) * (UCmigration_f(lb))));
    //CAN female removals at stage by CAN fishery
    Cexploit_f2(lb,t) = Cc_f2(lb,t)*(1.0-propfor) / Ctmp_f2(lb,t);
    //cout<<t<<" "<<lb<<" CAN female season 2 CAN removals "<<Cc_f2(lb,t)*(1.0-propfor)<<endl;
    //USA female removals at stage by CAN fishery
    //do not let the catch exceed the abundance (when including migrants)
    Cc_f2(lb,t)=min(value(Cc_f2(lb,t)),value(Ctmp_f2(lb,t) + (tmp_f2(lb,t)*UCmigration_f(lb))));
    exploit_f2(lb,t) = exploit_f2(lb,t) + ((Cc_f2(lb,t)*propfor) / tmp_f2(lb,t));
    Csf2(t,lb) = posfun((1. - Cexploit_f2(lb,t)) * mfexp(-natmortf(lb)*0.5),eps,projCfpensf2(t));
    Cn_f2(lb,t) = log(Ctmp_f2(lb,t) * Csf2(t,lb));
    CN_f2(lb,t) = mfexp(Cn_f2(lb,t));
    sf2(t,lb) = posfun((1. - exploit_f2(lb,t)) * mfexp(-natmortf(lb)*0.5),eps,projfpensf2(t));
    n_f2(lb,t) = log(tmp_f2(lb,t) * sf2(t,lb));
    N_f2(lb,t) = mfexp(n_f2(lb,t));
   vCsm1(t,1)=Csm1(t,1);  //Canadian male survival rate from fishing season 1
   vCsf1(t,1)=Csf1(t,1);  //Canadian female survival rate from fishing season 1
   vCsm2(t,1)=Csm2(t,1);  //Canadian male survival rate from fishing season 2
   vCsf2(t,1)=Csf2(t,1);  //Canadian female survival rate from fishing season 2
   vsm1(t,1)=sm1(t,1);  //US male survival rate from fishing season 1
   vsf1(t,1)=sf1(t,1);  //US female survival rate from fishing season 1
   vsm2(t,1)=sm2(t,1);  //US male survival rate from fishing season 2
   vsf2(t,1)=sf2(t,1);  //US female survival rate from fishing season 2
   vCsm1(t,2)=Csm1(t,2);  //Canadian male survival rate from fishing season 1
   vCsf1(t,2)=Csf1(t,2);  //Canadian female survival rate from fishing season 1
   vCsm2(t,2)=Csm2(t,2);  //Canadian male survival rate from fishing season 2
   vCsf2(t,2)=Csf2(t,2);  //Canadian female survival rate from fishing season 2
   vsm1(t,2)=sm1(t,2);  //US male survival rate from fishing season 1
   vsf1(t,2)=sf1(t,2);  //US female survival rate from fishing season 1
   vsm2(t,2)=sm2(t,2);  //US male survival rate from fishing season 2
   vsf2(t,2)=sf2(t,2);  //US female survival rate from fishing season 2
   }

   projpop(t,1)=N_m2(1,t);
   projpop(t,2)=N_m2(2,t);
   projpop(t,3)=N_f2(1,t);
   projpop(t,4)=N_f2(2,t);
   projpop(t,5)=CN_m2(1,t);
   projpop(t,6)=CN_m2(2,t);
   projpop(t,7)=CN_f2(1,t);
   projpop(t,8)=CN_f2(2,t);
   projpop(t,9)=exploit_m2(1,t)*(-(log(vsm2(t,1))))/(1-vsm2(t,1));
   projpop(t,10)=exploit_m2(2,t)*(-(log(vsm2(t,2))))/(1-vsm2(t,2));
   projpop(t,11)=exploit_f2(1,t)*(-(log(vsf2(t,1))))/(1-vsf2(t,1));
   projpop(t,12)=exploit_f2(2,t)*(-(log(vsf2(t,2))))/(1-vsf2(t,2));
   projpop(t,13)=Cexploit_m2(1,t)*(-(log(vCsm2(t,1))))/(1-vCsm2(t,1));
   projpop(t,14)=Cexploit_m2(2,t)*(-(log(vCsm2(t,2))))/(1-vCsm2(t,2));
   projpop(t,15)=Cexploit_f2(1,t)*(-(log(vCsf2(t,1))))/(1-vCsf2(t,1));
   projpop(t,16)=Cexploit_f2(2,t)*(-(log(vCsf2(t,2))))/(1-vCsf2(t,2));
   //combining regions and seasons for annual population component estimates
   totprojpop(t,1)=N_m2(1,t)+CN_m2(1,t);
   totprojpop(t,2)=N_m2(2,t)+CN_m2(2,t);
   totprojpop(t,3)=N_f2(1,t)+CN_f2(1,t);
   totprojpop(t,4)=N_f2(2,t)+CN_f2(2,t);
   totprojpop(t,5)=((exploit_m2(1,t)*(-(log(vsm2(t,1))))/(1-vsm2(t,1))*N_m2(1,t))+(Cexploit_m2(1,t)*(-
(log(vCsm2(t,1))))/(1-vCsm2(t,1))*CN_m2(1,t))+(exploit_m1(1,t)*(-(log(vsm1(t,1))))/(1-
vsm1(t,1))*N_m1(1,t))+(Cexploit_m1(1,t)*(-(log(vCsm1(t,1))))/(1-
vCsm1(t,1))*CN_m1(1,t)))/(N_m2(1,t)+CN_m2(1,t)+N_m1(1,t)+CN_m1(1,t));
   totprojpop(t,6)=((exploit_m2(2,t)*(-(log(vsm2(t,2))))/(1-vsm2(t,2))*N_m2(2,t))+(Cexploit_m2(2,t)*(-
(log(vCsm2(t,2))))/(1-vCsm2(t,2))*CN_m2(2,t))+(exploit_m1(2,t)*(-(log(vsm1(t,2))))/(1-
vsm1(t,2))*N_m1(2,t))+(Cexploit_m1(2,t)*(-(log(vCsm1(t,2))))/(1-
vCsm1(t,2))*CN_m1(2,t)))/(N_m2(2,t)+CN_m2(2,t)+N_m1(2,t)+CN_m1(2,t));
   totprojpop(t,7)=((exploit_f2(1,t)*(-(log(vsf2(t,1))))/(1-vsf2(t,1))*N_f2(1,t))+(Cexploit_f2(1,t)*(-
(log(vCsf2(t,1))))/(1-vCsf2(t,1))*CN_f2(1,t))+(exploit_f1(1,t)*(-(log(vsf1(t,1))))/(1-
vsf1(t,1))*N_f1(1,t))+(Cexploit_f1(1,t)*(-(log(vCsf1(t,1))))/(1-
vCsf1(t,1))*CN_f1(1,t)))/(N_f2(1,t)+CN_f2(1,t)+N_f1(1,t)+CN_f1(1,t));
   totprojpop(t,8)=((exploit_f2(2,t)*(-(log(vsf2(t,2))))/(1-vsf2(t,2))*N_f2(2,t))+(Cexploit_f2(2,t)*(-
(log(vCsf2(t,2))))/(1-vCsf2(t,2))*CN_f2(2,t))+(exploit_f1(2,t)*(-(log(vsf1(t,2))))/(1-
vsf1(t,2))*N_f1(2,t))+(Cexploit_f1(2,t)*(-(log(vCsf1(t,2))))/(1-
vCsf1(t,2))*CN_f1(2,t)))/(N_f2(2,t)+CN_f2(2,t)+N_f1(2,t)+CN_f1(2,t));
   if(mceval_phase()){
   ofstream projpopout("projpop.cha", ios::app);
   projpopout<<extract_row(projpop,t)<<endl;
   ofstream totprojpopout("totprojpop.cha", ios::app);
   totprojpopout<<extract_row(totprojpop,t)<<endl;
   }
   }


FUNCTION calc_obj_func
     dvar_vector fvec(1,824);
     fvec.initialize();//ensures initial values are zero
     resmj.initialize();//ensures initial values are zero
    resma.initialize();//ensures initial values are zero
    resfj.initialize();//ensures initial values are zero
    resfa.initialize();//ensures initial values are zero
    //population components by sex and stage; use end of season 1 for fitting to surveys; sigmas already logged
    //NOTE sigma's from data include process error, and scale may be unsuitable
    //NOTE the residual value is expressed as the log of the fraction obs/pred
    //population components by sex and stage
    //TRAC model survey sigma's include a constant process error of 0.209
    /*
    resmj(47,(nobs-3))=elem_div(log(elem_div(obs_mj(47,nobs-3),USAMJ(47,nobs-3))),stdev(47,nobs-3));
    resma(47,(nobs-3))=elem_div(log(elem_div(obs_ma(47,nobs-3),USAMA(47,nobs-3))),stdev(47,nobs-3));
    resfj(47,(nobs-3))=elem_div(log(elem_div(obs_fj(47,nobs-3),USAFJ(47,nobs-3))),stdev(47,nobs-3));
    resfa(47,(nobs-3))=elem_div(log(elem_div(obs_fa(47,nobs-3),USAFA(47,nobs-3))),stdev(47,nobs-3));
    resmjc=elem_div(log(elem_div(Cobs_mj(49,nobs),CANMJ(49,nobs))),Cstdev(49,nobs));
    resmac=elem_div(log(elem_div(Cobs_ma(49,nobs),CANMA(49,nobs))),Cstdev(49,nobs));
    resfjc=elem_div(log(elem_div(Cobs_fj(49,nobs),CANFJ(49,nobs))),Cstdev(49,nobs));
    resfac=elem_div(log(elem_div(Cobs_fa(49,nobs),CANFA(49,nobs))),Cstdev(49,nobs));
    */
    //Assuming current model covers process error
    //
    //resmj(47,(nobs-3))=elem_div(log(elem_div(obs_mj(47,(nobs-3)),USAMJ(47,(nobs-3)))),stdev(47,(nobs-3))-
0.209);
    //resma(47,(nobs-3))=elem_div(log(elem_div(obs_ma(47,(nobs-3)),USAMA(47,(nobs-3)))),stdev(47,(nobs-3))-
0.209);
    //resfj(47,(nobs-3))=elem_div(log(elem_div(obs_fj(47,(nobs-3)),USAFJ(47,(nobs-3)))),stdev(47,(nobs-3))-
0.209);
    //resfa(47,(nobs-3))=elem_div(log(elem_div(obs_fa(47,(nobs-3)),USAFA(47,(nobs-3)))),stdev(47,(nobs-3))-
0.209);
    resmj(47,nobs)=elem_div(log(elem_div(obs_mj(47,nobs),USAMJ(47,nobs))),stdev(47,nobs)-0.209);
    resma(47,nobs)=elem_div(log(elem_div(obs_ma(47,nobs),USAMA(47,nobs))),stdev(47,nobs)-0.209);
    resfj(47,nobs)=elem_div(log(elem_div(obs_fj(47,nobs),USAFJ(47,nobs))),stdev(47,nobs)-0.209);
    resfa(47,nobs)=elem_div(log(elem_div(obs_fa(47,nobs),USAFA(47,nobs))),stdev(47,nobs)-0.209);
    resmjc=elem_div(log(elem_div(Cobs_mj(49,nobs),CANMJ(49,nobs))),Cstdev(49,nobs)-0.209);
    resmac=elem_div(log(elem_div(Cobs_ma(49,nobs),CANMA(49,nobs))),Cstdev(49,nobs)-0.209);
    resfjc=elem_div(log(elem_div(Cobs_fj(49,nobs),CANFJ(49,nobs))),Cstdev(49,nobs)-0.209);
    resfac=elem_div(log(elem_div(Cobs_fa(49,nobs),CANFA(49,nobs))),Cstdev(49,nobs)-0.209);
    //
    sdmj = 0.5*norm2(resmj);
    sdma = 0.5*norm2(resma);
    sdfj = 0.5*norm2(resfj);
    sdfa = 0.5*norm2(resfa);
    sdmjc = 0.5*norm2(resmjc);
    sdmac = 0.5*norm2(resmac);
    sdfjc = 0.5*norm2(resfjc);
    sdfac = 0.5*norm2(resfac);
    fvec(1) = fabs(sdmj)*1.0;
    fvec(2) = fabs(sdma)*1.0;
    fvec(3) = fabs(sdfj)*1.0;
    fvec(4) = fabs(sdfa)*1.0;
    fvec(5) = fabs(sdmjc)*1.0;
    fvec(6) = fabs(sdmac)*1.0;
    fvec(7) = fabs(sdfjc)*1.0;
    fvec(8) = fabs(sdfac)*1.0;
    //catch components by sex, stage and season; sigmas already logged
    //
    catchresmj1=elem_div(log(elem_div(CatchUSAMJ1(1,nobs),PredCatchUSAMJ1(1,nobs))),SDUSA1(1,nobs));
    catchresma1=elem_div(log(elem_div(CatchUSAMA1(1,nobs),PredCatchUSAMA1(1,nobs))),SDUSA1(1,nobs));
    catchresfj1=elem_div(log(elem_div(CatchUSAFJ1(1,nobs),PredCatchUSAFJ1(1,nobs))),SDUSA1(1,nobs));
    catchresfa1=elem_div(log(elem_div(CatchUSAFA1(1,nobs),PredCatchUSAFA1(1,nobs))),SDUSA1(1,nobs));
    catchresmj2=elem_div(log(elem_div(CatchUSAMJ2(1,nobs),PredCatchUSAMJ2(1,nobs))),SDUSA2(1,nobs));
    catchresma2=elem_div(log(elem_div(CatchUSAMA2(1,nobs),PredCatchUSAMA2(1,nobs))),SDUSA2(1,nobs));
    catchresfj2=elem_div(log(elem_div(CatchUSAFJ2(1,nobs),PredCatchUSAFJ2(1,nobs))),SDUSA2(1,nobs));
    catchresfa2=elem_div(log(elem_div(CatchUSAFA2(1,nobs),PredCatchUSAFA2(1,nobs))),SDUSA2(1,nobs));
    catchresmjc1=elem_div(log(elem_div(CatchCANMJ1(1,nobs),PredCatchCANMJ1(1,nobs))),SDCAN1(1,nobs));
    catchresmac1=elem_div(log(elem_div(CatchCANMA1(1,nobs),PredCatchCANMA1(1,nobs))),SDCAN1(1,nobs));
    catchresfjc1=elem_div(log(elem_div(CatchCANFJ1(1,nobs),PredCatchCANFJ1(1,nobs))),SDCAN1(1,nobs));
    catchresfac1=elem_div(log(elem_div(CatchCANFA1(1,nobs),PredCatchCANFA1(1,nobs))),SDCAN1(1,nobs));
    catchresmjc2=elem_div(log(elem_div(CatchCANMJ2(1,nobs),PredCatchCANMJ2(1,nobs))),SDCAN2(1,nobs));
    catchresmac2=elem_div(log(elem_div(CatchCANMA2(1,nobs),PredCatchCANMA2(1,nobs))),SDCAN2(1,nobs));
    catchresfjc2=elem_div(log(elem_div(CatchCANFJ2(1,nobs),PredCatchCANFJ2(1,nobs))),SDCAN2(1,nobs));
    catchresfac2=elem_div(log(elem_div(CatchCANFA2(1,nobs),PredCatchCANFA2(1,nobs))),SDCAN2(1,nobs));
    //
    catchsdmj1 = 0.5*norm2(catchresmj1);
    catchsdma1 = 0.5*norm2(catchresma1);
    catchsdfj1 = 0.5*norm2(catchresfj1);
    catchsdfa1 = 0.5*norm2(catchresfa1);
    catchsdmjc1 = 0.5*norm2(catchresmjc1);
    catchsdmac1 = 0.5*norm2(catchresmac1);
    catchsdfjc1 = 0.5*norm2(catchresfjc1);
    catchsdfac1 = 0.5*norm2(catchresfac1);
    catchsdmj2 = 0.5*norm2(catchresmj2);
    catchsdma2 = 0.5*norm2(catchresma2);
    catchsdfj2 = 0.5*norm2(catchresfj2);
    catchsdfa2 = 0.5*norm2(catchresfa2);
    catchsdmjc2 = 0.5*norm2(catchresmjc2);
    catchsdmac2 = 0.5*norm2(catchresmac2);
    catchsdfjc2 = 0.5*norm2(catchresfjc2);
    catchsdfac2 = 0.5*norm2(catchresfac2);
    //
    fvec(9) = fabs(catchsdmj1);
    fvec(10) = fabs(catchsdma1);
    fvec(11) = fabs(catchsdfj1);
    fvec(12) = fabs(catchsdfa1);
    fvec(13) = fabs(catchsdmjc1);
    fvec(14) = fabs(catchsdmac1);
    fvec(15) = fabs(catchsdfjc1);
    fvec(16) = fabs(catchsdfac1);
    fvec(17) = fabs(catchsdmj2);
    fvec(18) = fabs(catchsdma2);
    fvec(19) = fabs(catchsdfj2);
    fvec(20) = fabs(catchsdfa2);
    fvec(21) = fabs(catchsdmjc2);
    fvec(22) = fabs(catchsdmac2);
    fvec(23) = fabs(catchsdfjc2);
    fvec(24) = fabs(catchsdfac2);
    //


    //If we want to put some variability on recruitment - straight
    /*
  for (int t=1; t<=nrobs; t++)  {
  for (int ni=1; ni<=nobs; ni++)  {
    if(it_yr(ni)==rec_yr(t)) {
    matchyr(t)=estrec(ni);
    //cout<<" ityr  "<<it_yr(ni)<<" recyr  "<<rec_yr(t)<<" est  "<<matchyr(t)<<" obs  "<<recobs(t)<<endl;
        }
    }
    }
    //resrec=elem_div(log(elem_div(recobs(1,nrobs),matchyr(1,nrobs))),sdrec);
    resrec=elem_div(log(recobs(1,nrobs)),log(matchyr(1,nrobs)))/sdrec;
    sdprec = 0.5*norm2(resrec);
    fvec(2) = 1*fabs(sdprec);
    */
    //If we want to put some variability on recruitment - In terms of pups per mom
    pupresrec=elem_div(log(elem_div(pups(35,nobs),pupfac(35,nobs))),sdrec(35,nobs));
    cpupresrec=elem_div(log(elem_div(cpups(35,nobs),cpupfac(35,nobs))),sdrec(35,nobs));
    //Might restrict the contribution to the likelihood to the survey years that provide observed size
composition
    //pupresrec=elem_div(log(elem_div(pups(47,nobs),pupfac(47,nobs))),sdrec(47,nobs));
    //cpupresrec=elem_div(log(elem_div(cpups(49,nobs),cpupfac(49,nobs))),sdrec(49,nobs));
    sdprec = 0.5*norm2(pupresrec);
    csdprec = 0.5*norm2(cpupresrec);
    //sdprec = 0.5*norm2(pupresrec(47,nobs));
    //csdprec = 0.5*norm2(cpupresrec(49,nobs));
  for (int i=1; i<=nobs; i++)  {
    fvec(28+i) = 10.*fpensm1(i);
    fvec(28+nobs+i) = 10.*fpensf1(i);
    fvec(28+nobs+nobs+i) = 10.*fpensm2(i);
    fvec(28+nobs+nobs+nobs+i) = 10.*fpensf2(i);
    fvec(28+nobs+nobs+nobs+nobs+i) = 10.*Cfpensm1(i);
    fvec(28+nobs+nobs+nobs+nobs+nobs+i) = 10.*Cfpensf1(i);
    fvec(28+nobs+nobs+nobs+nobs+nobs+nobs+i) = 10.*Cfpensm2(i);
    fvec(28+nobs+nobs+nobs+nobs+nobs+nobs+nobs+i) = 10.*Cfpensf2(i);
    }
    //If we want to put some variability on maturity theta
    //Might want to restrict the likelihood to survey years
    errthetamale=elem_div(log(elem_div(column(usagrowthmat,2)(35,nobs),extract_row(thetavarusa,1))),sdtheta(35,
nobs));
    errthetafemale=elem_div(log(elem_div(column(usagrowthmat,3)(35,nobs),extract_row(thetavarusa,2))),sdtheta(3
5,nobs));
    cerrthetamale=elem_div(log(elem_div(column(cangrowthmat,2)(35,nobs),extract_row(thetavarcan,1))),sdtheta(35
,nobs));
    cerrthetafemale=elem_div(log(elem_div(column(cangrowthmat,3)(35,nobs),extract_row(thetavarcan,2))),sdtheta(
35,nobs));
    sdthetamale = 0.5*norm2(errthetamale);
    sdthetafemale = 0.5*norm2(errthetafemale);
    csdthetamale = 0.5*norm2(cerrthetamale);
    csdthetafemale = 0.5*norm2(cerrthetafemale);
    //zero the penalty to see where theta works mathematically
    //fvec(25) = 0;
    fvec(25) = 2*(fabs(sdthetamale)+fabs(sdthetafemale)+fabs(csdthetamale)+fabs(csdthetafemale));
    //Penalty on deviation from mean migration estimate
  for (i=47; i<=nobs; i++)  {
    errcumigjm(i)=log(CUmigration_m(1)/(varCUmigration_m(1,i)*CUmigration_m(1)))/sdmig;
    errcumigam(i)=log(CUmigration_m(2)/(varCUmigration_m(2,i)*CUmigration_m(2)))/sdmig;
    errcumigjf(i)=log(CUmigration_f(1)/(varCUmigration_f(1,i)*CUmigration_f(1)))/sdmig;
    errcumigaf(i)=log(CUmigration_f(2)/(varCUmigration_f(2,i)*CUmigration_f(2)))/sdmig;
    errucmigjm(i)=log(UCmigration_m(1)/(varUCmigration_m(1,i)*UCmigration_m(1)))/sdmig;
    errucmigam(i)=log(UCmigration_m(2)/(varUCmigration_m(2,i)*UCmigration_m(2)))/sdmig;
    errucmigjf(i)=log(UCmigration_f(1)/(varUCmigration_f(1,i)*UCmigration_f(1)))/sdmig;
    errucmigaf(i)=log(UCmigration_f(2)/(varUCmigration_f(2,i)*UCmigration_f(2)))/sdmig;
        }
    sdcumigjm = 0.5*norm2(errcumigjm);
    sdcumigam = 0.5*norm2(errcumigam);
    sdcumigjf = 0.5*norm2(errcumigjf);
    sdcumigaf = 0.5*norm2(errcumigaf);
    sducmigjm = 0.5*norm2(errucmigjm);
    sducmigam = 0.5*norm2(errucmigam);
    sducmigjf = 0.5*norm2(errucmigjf);
    sducmigaf = 0.5*norm2(errucmigaf);
    fvec(26) = fabs(sdprec)+fabs(csdprec);
    fvec(27) =
1.0*(fabs(sdcumigjm)+fabs(sdcumigam)+fabs(sdcumigjf)+fabs(sdcumigaf)+fabs(sducmigjm)+fabs(sducmigam)+fabs(sducm
igjf)+fabs(sducmigaf));
    //Penalty on deviation from mean Q estimate;
  for (int ys=1; ys<=48; ys++)  {
    fpenprop(5,ys)=0;
    fpenprop(6,ys)=0;
    fpenprop(7,ys)=0;
    fpenprop(8,ys)=0;
        }
  for (ys=1; ys<=46; ys++)  {
    fpenprop(1,ys)=0;
    fpenprop(2,ys)=0;
    fpenprop(3,ys)=0;
    fpenprop(4,ys)=0;
        }
  for (ys=49; ys<=60; ys++)  {
    fpenprop(5,ys)=log(mfexp(CANloggATC_mj)/(mfexp(CANloggATC_mj)*fCANlogq_mj(ys)))/sdq;
    fpenprop(6,ys)=log(mfexp(CANloggATC_ma)/(mfexp(CANloggATC_ma)*fCANlogq_ma(ys)))/sdq;
    fpenprop(7,ys)=log(mfexp(CANloggATC_fj)/(mfexp(CANloggATC_fj)*fCANlogq_fj(ys)))/sdq;
    fpenprop(8,ys)=log(mfexp(CANloggATC_fa)/(mfexp(CANloggATC_fa)*fCANlogq_fa(ys)))/sdq;
        }
  for (ys=61; ys<=nobs; ys++)  {
    fpenprop(5,ys)=log(mfexp(CANlogq_mj)/(mfexp(CANlogq_mj)*fCANlogq_mj(ys)))/sdq;
    fpenprop(6,ys)=log(mfexp(CANlogq_ma)/(mfexp(CANlogq_ma)*fCANlogq_ma(ys)))/sdq;
    fpenprop(7,ys)=log(mfexp(CANlogq_fj)/(mfexp(CANlogq_fj)*fCANlogq_fj(ys)))/sdq;
    fpenprop(8,ys)=log(mfexp(CANlogq_fa)/(mfexp(CANlogq_fa)*fCANlogq_fa(ys)))/sdq;
        }
  for (ys=47; ys<=66; ys++)  {
    fpenprop(1,ys)=log(mfexp(USAlogq1_mj)/(mfexp(USAlogq1_mj)*fUSAlogq_mj(ys)))/sdq;
    fpenprop(2,ys)=log(mfexp(USAlogq1_ma)/(mfexp(USAlogq1_ma)*fUSAlogq_ma(ys)))/sdq;
    fpenprop(3,ys)=log(mfexp(USAlogq1_fj)/(mfexp(USAlogq1_fj)*fUSAlogq_fj(ys)))/sdq;
    fpenprop(4,ys)=log(mfexp(USAlogq1_fa)/(mfexp(USAlogq1_fa)*fUSAlogq_fa(ys)))/sdq;
        }
  for (ys=67; ys<=78; ys++)  {
    fpenprop(1,ys)=log(mfexp(USAlogq2_mj)/(mfexp(USAlogq2_mj)*fUSAlogq_mj(ys)))/sdq;
    fpenprop(2,ys)=log(mfexp(USAlogq2_ma)/(mfexp(USAlogq2_ma)*fUSAlogq_ma(ys)))/sdq;
    fpenprop(3,ys)=log(mfexp(USAlogq2_fj)/(mfexp(USAlogq2_fj)*fUSAlogq_fj(ys)))/sdq;
    fpenprop(4,ys)=log(mfexp(USAlogq2_fa)/(mfexp(USAlogq2_fa)*fUSAlogq_fa(ys)))/sdq;
        }
    //TrawlGate
   for (ys=79; ys<=81; ys++)  {
    fpenprop(1,ys)=log(mfexp(USAlogq3_mj)/(mfexp(USAlogq3_mj)*fUSAlogq_mj(ys)))/sdq;
    fpenprop(2,ys)=log(mfexp(USAlogq3_ma)/(mfexp(USAlogq3_ma)*fUSAlogq_ma(ys)))/sdq;
    fpenprop(3,ys)=log(mfexp(USAlogq3_fj)/(mfexp(USAlogq3_fj)*fUSAlogq_fj(ys)))/sdq;
    fpenprop(4,ys)=log(mfexp(USAlogq3_fa)/(mfexp(USAlogq3_fa)*fUSAlogq_fa(ys)))/sdq;
        }
  for (ys=82; ys<=87; ys++)  {
    fpenprop(1,ys)=log(mfexp(USAlogq2_mj)/(mfexp(USAlogq2_mj)*fUSAlogq_mj(ys)))/sdq;
    fpenprop(2,ys)=log(mfexp(USAlogq2_ma)/(mfexp(USAlogq2_ma)*fUSAlogq_ma(ys)))/sdq;
    fpenprop(3,ys)=log(mfexp(USAlogq2_fj)/(mfexp(USAlogq2_fj)*fUSAlogq_fj(ys)))/sdq;
    fpenprop(4,ys)=log(mfexp(USAlogq2_fa)/(mfexp(USAlogq2_fa)*fUSAlogq_fa(ys)))/sdq;
        }
 for (ys=88; ys<=nobs; ys++)  {
    fpenprop(1,ys)=log(mfexp(USAlogq4_mj)/(mfexp(USAlogq4_mj)*fUSAlogq_mj(ys)))/sdq;
    fpenprop(2,ys)=log(mfexp(USAlogq4_ma)/(mfexp(USAlogq4_ma)*fUSAlogq_ma(ys)))/sdq;
    fpenprop(3,ys)=log(mfexp(USAlogq4_fj)/(mfexp(USAlogq4_fj)*fUSAlogq_fj(ys)))/sdq;
    fpenprop(4,ys)=log(mfexp(USAlogq4_fa)/(mfexp(USAlogq4_fa)*fUSAlogq_fa(ys)))/sdq;
        }
    sdq1 = 0.5*norm2(row(fpenprop,1));
    sdq2 = 0.5*norm2(row(fpenprop,2));
    sdq3 = 0.5*norm2(row(fpenprop,3));
    sdq4 = 0.5*norm2(row(fpenprop,4));
    sdq5 = 0.5*norm2(row(fpenprop,5));
    sdq6 = 0.5*norm2(row(fpenprop,6));
    sdq7 = 0.5*norm2(row(fpenprop,7));
    sdq8 = 0.5*norm2(row(fpenprop,8));
    fvec(28) = fabs(sdq1)+fabs(sdq2)+fabs(sdq3)+fabs(sdq4)+fabs(sdq5)+fabs(sdq6)+fabs(sdq7)+fabs(sdq8);
    fvecout = fvec;
    f = sum(fvec);
```

```
REPORT_SECTION

     if(current_phase()>=1) {
     ofstream sbm("sbm",ios::trunc);
     ofstream popest("PopEst.out",ios::trunc);
     ofstream popestS1("PopEstS1.out",ios::trunc);
     ofstream opr("ObsPreRes.out",ios::trunc);
     ofstream copr("CatchObsPreRes.out",ios::trunc);
     ofstream fmnm("NatMortExpRate.out",ios::trunc);
     ofstream qcan("QCAN.out",ios::trunc);
     ofstream qusa("QUSA.out",ios::trunc);
     ofstream stockest("CanStockEst.out",ios::trunc);
     sbm<<"phase1 "<<iters_phase1<<endl;
     sbm<<"phase2 "<<iters_phase2<<endl;
     sbm<<"phase3 "<<iters_phase3<<endl;
     sbm<<"phase4 "<<iters_phase4<<endl;
     sbm<<"phase5 "<<iters_phase5<<endl;
     sbm<<"phase6 "<<iters_phase6<<endl;
     sbm<<"phase7 "<<iters_phase7<<endl;
     sbm<<"OFV "<<f<<endl;
     sbm<<"LIKELIHOOD COMPONENTS"<<endl;
     sbm<<"sdmj sdma sdfj sdfa "<<endl;
     sbm<<"fvec "<<fvecout(1,4)<<endl;
     sbm<<"sdmjc sdmac sdfjc sdfac "<<endl;
     sbm<<"fvec "<<fvecout(5,8)<<endl;
     sbm<<"USA season 1 catchsdmj catchsdma catchsdfj catchsdfa "<<endl;
     sbm<<"fvec "<<fvecout(9,12)<<endl;
     sbm<<"USA season 2 catchsdmj catchsdma catchsdfj catchsdfa "<<endl;
     sbm<<"fvec "<<fvecout(17,20)<<endl;
     sbm<<"CAN season 1 catchsdmjc catchsdmac catchsdfjc catchsdfac "<<endl;
     sbm<<"fvec "<<fvecout(13,16)<<endl;
     sbm<<"CAN season 2 catchsdmjc catchsdmac catchsdfjc catchsdfac "<<endl;
     sbm<<"fvec "<<fvecout(21,24)<<endl;
     sbm<<"US_Males: "<<sdthetamale<<"US_Females: "<<sdthetafemale<<"Can_Males: "<<csdthetamale<<"Can_Females:
"<<csdthetafemale<<endl;
     sbm<<"Estimate of Recruitment Process Error if implemented"<<endl;
     sbm<<"sdprec+csdprec "<<fvecout(26)<<endl;
     sbm<<"Total of Q Penalties if implemented"<<fvecout(420)<<endl;
     sbm<<"Initial Estimated Abundance 1922 - starting numbers, estimated but not part of likelihood"<<endl;
     sbm<<"Canada "<<"Juvenile_Males "<<(CN_fa)*N_m1(1,1)<<" Adult_Males "<<(CN_fa)*N_m1(2,1)<<"
Juvenile_Females "<<(CN_fa)*N_f1(1,1)<<" Adult_Females "<<(CN_fa)*N_f1(2,1)<<endl;
     sbm<<"USA "<<"Juvenile_Males "<<(N_m1(1,1))<<" Adult_Males "<<(N_m1(2,1))<<" Juvenile_Females
"<<(N_f1(1,1))<<" Adult_Females "<<(N_f1(2,1))<<endl;
     sbm<<"Penalty for migration deviation "<<fvecout(419)<<endl;
     sbm<<"PARAMETER VALUES"<<endl;
     sbm<<"Survey Catchability by Sex and Stage"<<endl;
     sbm<<"USA males "<<exp(USAlogq1_mj)<<"   "<<exp(USAlogq1_ma)<<endl;
     sbm<<"USA females "<<exp(USAlogq1_fj)<<"   "<<exp(USAlogq1_fa)<<endl;
     sbm<<"USA males "<<exp(USAlogq2_mj)<<"   "<<exp(USAlogq2_ma)<<endl;
     sbm<<"USA females "<<exp(USAlogq2_fj)<<"   "<<exp(USAlogq2_fa)<<endl;
     sbm<<"USA males "<<exp(USAlogq3_mj)<<"   "<<exp(USAlogq3_ma)<<endl;
     sbm<<"USA females "<<exp(USAlogq3_fj)<<"   "<<exp(USAlogq3_fa)<<endl;
     sbm<<"USA males "<<exp(USAlogq4_mj)<<"   "<<exp(USAlogq4_ma)<<endl;
     sbm<<"USA females "<<exp(USAlogq4_fj)<<"   "<<exp(USAlogq4_fa)<<endl;
     sbm<<"CAN males "<<exp(CANlogqATC_mj)<<"   "<<exp(CANlogqATC_ma)<<endl;
     sbm<<"CAN females "<<exp(CANlogqATC_fj)<<"   "<<exp(CANlogqATC_fa)<<endl;
     sbm<<"CAN males "<<exp(CANlogq_mj)<<"   "<<exp(CANlogq_ma)<<endl;
     sbm<<"CAN females "<<exp(CANlogq_fj)<<"   "<<exp(CANlogq_fa)<<endl;
     sbm<<"Recruitment (pups per mom)"<<endl;
     sbm<<"Year USA Deterministic     Estimated   CAN Deterministic     Estimated"<<endl;
     for (int yi=35; yi<=nobs; yi++) {
     sbm<<it_yr(yi)<<" "<<pups(yi)<<" "<<pupfac(yi)<<" "<<cpups(yi)<<" "<<cpupfac(yi)<<endl;
     }
     sbm<<"Error on thetas Absolute Values Total: "<<fvecout(25)<<endl;
     sbm<<"Year Male Deterministic Estimated Female Deterministic Estimated"<<endl;
     sbm<<"USA"<<endl;
     for (yi=35; yi<=nobs; yi++) {
     sbm<<it_yr(yi)<<" "<<usagrowthmat(yi,2)<<" "<<thetavarusa(1,yi)<<" "<<usagrowthmat(yi,3)<<"
"<<thetavarusa(2,yi)<<endl;
     }
     sbm<<"CAN"<<endl;
     for (yi=35; yi<=nobs; yi++) {
     sbm<<it_yr(yi)<<" "<<cangrowthmat(yi,2)<<" "<<thetavarcan(1,yi)<<" "<<cangrowthmat(yi,3)<<"
"<<thetavarcan(2,yi)<<endl;
     }
     sbm<<"Migrations by Sex and Stage - Mj MA FJ FA"<<endl;
     for (yi=47; yi<=nobs; yi++) {
     sbm<<"CAN to USA Season 1 "<<(varCUmigration_m(1,yi)*CUmigration_m(1))<<"
"<<(varCUmigration_m(2,yi)*CUmigration_m(2))<<" "<<(varCUmigration_f(1,yi)*CUmigration_f(1))<<"
"<<(varCUmigration_f(2,yi)*CUmigration_f(2))<<endl;
     }
     for (yi=47; yi<=nobs; yi++) {
```

```
    sbm<<"USA to CAN Season 2 "<<(varUCmigration_m(1,yi)*UCmigration_m(1))<<"
"<<(varUCmigration_m(2,yi)*UCmigration_m(2))<<" "<<(varUCmigration_f(1,yi)*UCmigration_f(1))<<"
"<<(varUCmigration_f(2,yi)*UCmigration_f(2))<<endl;
    }
    sbm<<"likelihood components - zero abundance penalties USA: fpensm1 fpensf1 fpensm2 fpensf2"<<endl;
    for (yi=1; yi<=nobs; yi++) {
    sbm<<it_yr(yi)<<" "<<fvecout(28+yi)<<" "<<fvecout(28+nobs+yi)<<" "<<fvecout(28+ncbs+nobs+yi)<<"
"<<fvecout(28+nobs+nobs+nobs+yi)<<endl;
    }
    sbm<<"likelihood components - zero abundance penalties CAN: Cfpensm1 Cfpensf1 Cfpensm2 Cfpensf2"<<endl;
    for (yi=1; yi<=nobs; yi++) {
    sbm<<it_yr(yi)<<" "<<fvecout(28+nobs+nobs+nobs+nobs+yi)<<" "<<fvecout(28+nobs+nobs+nobs+nobs+nobs+yi)<<"
"<<fvecout(28+nobs+nobs+nobs+nobs+nobs+nobs+yi)<<" "<<fvecout(28+nobs+nobs+nobs+nobs+nobs+nobs+nobs+yi)<<endl;
    }
    qcan<<"Year MeanMJ MJ MeanMA MA MeanFJ FJ MeanFA FA"<<endl;
    for (yi=49; yi<=60; yi++) {
    qcan<<it_yr(yi)<<" "<<exp(CANloggATC_mj)<<" "<<(exp(CANloggATC_mj)*fCANlogq_mj(yi))<<"
"<<exp(CANloggATC_ma)<<" "<<(exp(CANloggATC_ma)*fCANlogq_ma(yi))<<" "<<exp(CANloggATC_fj)<<"
"<<(exp(CANloggATC_fj)*fCANlogq_fj(yi))<<" "<<exp(CANloggATC_fa)<<"
"<<(exp(CANloggATC_fa)*fCANlogq_fa(yi))<<endl;
    }
    for (yi=61; yi<=nobs; yi++) {
    qcan<<it_yr(yi)<<" "<<exp(CANlogq_mj)<<" "<<(exp(CANlogq_mj)*fCANlogq_mj(yi))<<" "<<exp(CANlogq_ma)<<"
"<<(exp(CANlogq_ma)*fCANlogq_ma(yi))<<" "<<exp(CANlogq_fj)<<" "<<(exp(CANlogq_fj)*fCANlogq_fj(yi))<<"
"<<exp(CANlogq_fa)<<" "<<(exp(CANlogq_fa)*fCANlogq_fa(yi))<<endl;
    }
    qusa<<"Year MeanMJ MJ MeanMA MA MeanFJ FJ MeanFA FA"<<endl;
  for (yi=47; yi<=66; yi++)  {
    qusa<<it_yr(yi)<<" "<<exp(USAlogq1_mj)<<" "<<(exp(USAlogq1_mj)*fUSAlogq_mj(yi))<<" "<<exp(USAlogq1_ma)<<"
"<<(exp(USAlogq1_ma)*fUSAlogq_ma(yi))<<" "<<exp(USAlogq1_fj)<<" "<<(exp(USAlogq1_fj)*fUSAlogq_fj(yi))<<"
"<<exp(USAlogq1_fa)<<" "<<(exp(USAlogq1_fa)*fUSAlogq_fa(yi))<<endl;
        }
  for (yi=67; yi<=78; yi++)  {
    qusa<<it_yr(yi)<<" "<<exp(USAlogq2_mj)<<" "<<(exp(USAlogq2_mj)*fUSAlogq_mj(yi))<<" "<<exp(USAlogq2_ma)<<"
"<<(exp(USAlogq2_ma)*fUSAlogq_ma(yi))<<" "<<exp(USAlogq2_fj)<<" "<<(exp(USAlogq2_fj)*fUSAlogq_fj(yi))<<"
"<<exp(USAlogq2_fa)<<" "<<(exp(USAlogq2_fa)*fUSAlogq_fa(yi))<<endl;
        }
  for (yi=79; yi<=81; yi++)  {
    qusa<<it_yr(yi)<<" "<<exp(USAlogq3_mj)<<" "<<(exp(USAlogq3_mj)*fUSAlogq_mj(yi))<<" "<<exp(USAlogq3_ma)<<"
"<<(exp(USAlogq3_ma)*fUSAlogq_ma(yi))<<" "<<exp(USAlogq3_fj)<<" "<<(exp(USAlogq3_fj)*fUSAlogq_fj(yi))<<"
"<<exp(USAlogq3_fa)<<" "<<(exp(USAlogq3_fa)*fUSAlogq_fa(yi))<<endl;
        }
  for (yi=82; yi<=87; yi++)  {
    qusa<<it_yr(yi)<<" "<<exp(USAlogq2_mj)<<" "<<(exp(USAlogq2_mj)*fUSAlogq_mj(yi))<<" "<<exp(USAlogq2_ma)<<"
"<<(exp(USAlogq2_ma)*fUSAlogq_ma(yi))<<" "<<exp(USAlogq2_fj)<<" "<<(exp(USAlogq2_fj)*fUSAlogq_fj(yi))<<"
"<<exp(USAlogq2_fa)<<" "<<(exp(USAlogq2_fa)*fUSAlogq_fa(yi))<<endl;
        }
  for (yi=88; yi<=nobs; yi++)  {
    qusa<<it_yr(yi)<<" "<<exp(USAlogq4_mj)<<" "<<(exp(USAlogq4_mj)*fUSAlogq_mj(yi))<<" "<<exp(USAlogq4_ma)<<"
"<<(exp(USAlogq4_ma)*fUSAlogq_ma(yi))<<" "<<exp(USAlogq4_fj)<<" "<<(exp(USAlogq4_fj)*fUSAlogq_fj(yi))<<"
"<<exp(USAlogq4_fa)<<" "<<(exp(USAlogq4_fa)*fUSAlogq_fa(yi))<<endl;
        }
    //MSY; first if to skip it
    if(current_phase()==lastphase) {
    int reg;
    reg=1;
    calculate_reference_points(reg);
    sbm<<"Reference Point Estimates - MSY based; USA"<<endl;
    sbm<<"In millions of fish"<<endl;
    sbm<<"Varying Intrinsic Rate of Population Growth"<<endl;
    sbm<<"GrowthRate Shape Capacity Bmsy MSY Fmsy"<<endl;
    for (int mf=1; mf<=20; mf++) {
    if(mf==11) sbm<<"Varying Shape Parameter"<<endl;
    if(mf==11) sbm<<"GrowthRate Shape Capacity Bmsy MSY Fmsy"<<endl;
    sbm<<rstep(mf)<<"   "<<zstep(mf)<<"   "<<kstep(mf)/1000000<<"   "<<bmsystep(mf)/1000000<<"
"<<msystep(mf)/1000000<<"   "<<fmsystep(mf)<<endl;
    }
    sbm<<"In tons of fish (approximated as 740 fish/ton total biomass)"<<endl;
    //Numbers to tons based on 1985-1988 Summer RV;
    sbm<<"Varying Intrinsic Rate of Population Growth"<<endl;
    sbm<<"GrowthRate Shape Capacity Bmsy MSY Fmsy"<<endl;
    for (mf=1; mf<=20; mf++) {
    if(mf==11) sbm<<"Varying Shape Parameter"<<endl;
    If(mf==11) sbm<<"GrowthRate Shape Capacity Bmsy MSY Fmsy"<<endl;
    //For total biomass; MSY corresponds to period when K and r determined
    //For SSB; MSY corresponds to period when K and r determined
    sbm<<rstep(mf)<<"   "<<zstep(mf)<<"   "<<kstep(mf)/740<<"   "<<bmsystep(mf)/740<<"   "<<msystep(mf)/740<<"
"<<fmsystep(mf)<<endl;
    }
    reg=2;
    calculate_reference_points(reg);
    sbm<<"Reference Point Estimates - MSY based; CAN"<<endl;
    sbm<<"In millions of fish"<<endl;
    sbm<<"Varying Intrinsic Rate of Population Growth"<<endl;
    sbm<<"GrowthRate Shape Capacity Bmsy MSY Fmsy"<<endl;
    for (mf=1; mf<=20; mf++) {
    if(mf==11) sbm<<"Varying Shape Parameter"<<endl;
    if(mf==11) sbm<<"GrowthRate Shape Capacity Bmsy MSY Fmsy"<<endl;
    sbm<<rstep(mf)<<"   "<<zstep(mf)<<"   "<<kstep(mf)/1000000<<"   "<<bmsystep(mf)/1000000<<"
"<<msystep(mf)/1000000<<"   "<<fmsystep(mf)<<endl;
    }
    sbm<<"In tons of fish (approximated as 740 fish/ton total biomass)"<<endl;
    sbm<<"Varying Intrinsic Rate of Population Growth"<<endl;
    sbm<<"GrowthRate Shape Capacity Bmsy MSY Fmsy"<<endl;
    for (mf=1; mf<=20; mf++) {
    if(mf==11) sbm<<"Varying Shape Parameter"<<endl;
    if(mf==11) sbm<<"GrowthRate Shape Capacity Bmsy MSY Fmsy"<<endl;
    sbm<<rstep(mf)<<"   "<<zstep(mf)<<"   "<<kstep(mf)/740<<"   "<<bmsystep(mf)/740<<"   "<<msystep(mf)/740<<"
"<<fmsystep(mf)<<endl;
    }
    }
    popest<<"Year Sex Stage USA CAN"<<endl;
    for (int i=1; i<=192; i++) {
    popest<<1921+i<<" 1 1 "<<N_m2(1,i)<<" "<<CN_m2(1,i)<<endl;
    popest<<1921+i<<" 1 2 "<<N_m2(2,i)<<" "<<CN_m2(2,i)<<endl;
    popest<<1921+i<<" 2 1 "<<N_f2(1,i)<<" "<<CN_f2(1,i)<<endl;
    popest<<1921+i<<" 2 2 "<<N_f2(2,i)<<" "<<CN_f2(2,i)<<endl;
    }
    popestS1<<"Year Sex Stage USA CAN"<<endl;
    for (int i=1; i<=192; i++) {
    popestS1<<1921+i<<" 1 1 "<<N_m1(1,i)<<" "<<CN_m1(1,i)<<endl;
    popestS1<<1921+i<<" 1 2 "<<N_m1(2,i)<<" "<<CN_m1(2,i)<<endl;
    popestS1<<1921+i<<" 2 1 "<<N_f1(1,i)<<" "<<CN_f1(1,i)<<endl;
    popestS1<<1921+i<<" 2 2 "<<N_f1(2,i)<<" "<<CN_f1(2,i)<<endl;
    }
    opr<<"Region Year Sex Stage Obs Pred Res"<<endl;
    for (i=47; i<=nobs; i++) {
    opr<<" 2 "<<it_yr(i)<<" 1 1 "<<obs_mj(i)<<" "<<USAMJ(i)<<" "<<resmj(i)<<endl;
    opr<<" 2 "<<it_yr(i)<<" 1 2 "<<obs_ma(i)<<" "<<USAMA(i)<<" "<<resma(i)<<endl;
    opr<<" 2 "<<it_yr(i)<<" 2 1 "<<obs_fj(i)<<" "<<USAFJ(i)<<" "<<resfj(i)<<endl;
    opr<<" 2 "<<it_yr(i)<<" 2 2 "<<obs_fa(i)<<" "<<USAFA(i)<<" "<<resfa(i)<<endl;
    }
    for (i=49; i<=nobs; i++) {
    opr<<" 1 "<<it_yr(i)<<" 1 1 "<<Cobs_mj(i)<<" "<<CANMJ(i)<<" "<<resmjc(i)<<endl;
    opr<<" 1 "<<it_yr(i)<<" 1 2 "<<Cobs_ma(i)<<" "<<CANMA(i)<<" "<<resmac(i)<<endl;
    opr<<" 1 "<<it_yr(i)<<" 2 1 "<<Cobs_fj(i)<<" "<<CANFJ(i)<<" "<<resfjc(i)<<endl;
    opr<<" 1 "<<it_yr(i)<<" 2 2 "<<Cobs_fa(i)<<" "<<CANFA(i)<<" "<<resfac(i)<<endl;
    }
    stockest<<"Region Year Sex Stage StockAbun"<<endl;
    for (i=49; i<=nobs; i++) {
    if(i<=60) {
    stockest<<" 1 "<<it_yr(i)<<" 1 1 "<<" "<<CANMJ(i)/exp(CANlogqATC_mj)<<endl;
    stockest<<" 1 "<<it_yr(i)<<" 1 2 "<<" "<<CANMA(i)/exp(CANlogqATC_ma)<<endl;
    stockest<<" 1 "<<it_yr(i)<<" 2 1 "<<" "<<CANFJ(i)/exp(CANlogqATC_fj)<<endl;
    stockest<<" 1 "<<it_yr(i)<<" 2 2 "<<" "<<CANFA(i)/exp(CANlogqATC_fa)<<endl;
    }
    if(i>60) {
    stockest<<" 1 "<<it_yr(i)<<" 1 1 "<<" "<<CANMJ(i)/exp(CANlogq_mj)<<endl;
    stockest<<" 1 "<<it_yr(i)<<" 1 2 "<<" "<<CANMA(i)/exp(CANlogq_ma)<<endl;
    stockest<<" 1 "<<it_yr(i)<<" 2 1 "<<" "<<CANFJ(i)/exp(CANlogq_fj)<<endl;
    stockest<<" 1 "<<it_yr(i)<<" 2 2 "<<" "<<CANFA(i)/exp(CANlogq_fa)<<endl;
    }
    }
    copr<<"Region Season Year Sex Stage Obs Pred Res"<<endl;
    for (i=1; i<=nobs; i++) {
    copr<<" 2 1 "<<it_yr(i)<<" 1 1 "<<CatchUSAMJ1(i)<<" "<<PredCatchUSAMJ1(i)<<" "<<catchresmj1(i)<<endl;
    copr<<" 2 1 "<<it_yr(i)<<" 1 2 "<<CatchUSAMA1(i)<<" "<<PredCatchUSAMA1(i)<<" "<<catchresma1(i)<<endl;
    copr<<" 2 1 "<<it_yr(i)<<" 2 1 "<<CatchUSAFJ1(i)<<" "<<PredCatchUSAFJ1(i)<<" "<<catchresfj1(i)<<endl;
    copr<<" 2 1 "<<it_yr(i)<<" 2 2 "<<CatchUSAFA1(i)<<" "<<PredCatchUSAFA1(i)<<" "<<catchresfa1(i)<<endl;
    copr<<" 2 2 "<<it_yr(i)<<" 1 1 "<<CatchUSAMJ2(i)<<" "<<PredCatchUSAMJ2(i)<<" "<<catchresmj2(i)<<endl;
    copr<<" 2 2 "<<it_yr(i)<<" 1 2 "<<CatchUSAMA2(i)<<" "<<PredCatchUSAMA2(i)<<" "<<catchresma2(i)<<endl;
    copr<<" 2 2 "<<it_yr(i)<<" 2 1 "<<CatchUSAFJ2(i)<<" "<<PredCatchUSAFJ2(i)<<" "<<catchresfj2(i)<<endl;
    copr<<" 2 2 "<<it_yr(i)<<" 2 2 "<<CatchUSAFA2(i)<<" "<<PredCatchUSAFA2(i)<<" "<<catchresfa2(i)<<endl;
    }
    for (i=1; i<=nobs; i++) {
    copr<<" 1 1 "<<it_yr(i)<<" 1 1 "<<CatchCANMJ1(i)<<" "<<PredCatchCANMJ1(i)<<" "<<catchresmjc1(i)<<endl;
    copr<<" 1 1 "<<it_yr(i)<<" 1 2 "<<CatchCANMA1(i)<<" "<<PredCatchCANMA1(i)<<" "<<catchresmac1(i)<<endl;
    copr<<" 1 1 "<<it_yr(i)<<" 2 1 "<<CatchCANFJ1(i)<<" "<<PredCatchCANFJ1(i)<<" "<<catchresfjc1(i)<<endl;
    copr<<" 1 1 "<<it_yr(i)<<" 2 2 "<<CatchCANFA1(i)<<" "<<PredCatchCANFA1(i)<<" "<<catchresfac1(i)<<endl;
    copr<<" 1 2 "<<it_yr(i)<<" 1 1 "<<CatchCANMJ2(i)<<" "<<PredCatchCANMJ2(i)<<" "<<catchresmjc2(i)<<endl;
    copr<<" 1 2 "<<it_yr(i)<<" 1 2 "<<CatchCANMA2(i)<<" "<<PredCatchCANMA2(i)<<" "<<catchresmac2(i)<<endl;
    copr<<" 1 2 "<<it_yr(i)<<" 2 1 "<<CatchCANFJ2(i)<<" "<<PredCatchCANFJ2(i)<<" "<<catchresfjc2(i)<<endl;
    copr<<" 1 2 "<<it_yr(i)<<" 2 2 "<<CatchCANFA2(i)<<" "<<PredCatchCANFA2(i)<<" "<<catchresfac2(i)<<endl;
    }
    fmnm<<"Region Year Season Sex Stage ExpRate SurvRate FishMort"<<endl;
    for (int n=1; n<=(nobs+ProjYrs); n++) {
    fmnm<<" 2 "<<1921+n<<" 1 1 1 "<<exploit_m1(1,n)<<" "<<vsm1(n,1)<<" "<<exploit_m1(1,n)*(-
(log(vsm1(n,1)))/(1-vsm1(n,1))<<endl;
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	fmnm<<" 2 "<<1921+n<<" 1 1 2 "<<exploit_m1(2,n)<<" "<<vsm1(n,2)<<" "<<exploit_m1(2,n)*(-
(log(vsm1(n,2))))/(1-vsm1(n,2))<<endl;
	fmnm<<" 2 "<<1921+n<<" 1 2 1 "<<exploit_f1(1,n)<<" "<<vsf1(n,1)<<" "<<exploit_f1(1,n)*(-
(log(vsf1(n,1))))/(1-vsf1(n,1))<<endl;
	fmnm<<" 2 "<<1921+n<<" 1 2 2 "<<exploit_f1(2,n)<<" "<<vsf1(n,2)<<" "<<exploit_f1(2,n)*(-
(log(vsf1(n,2))))/(1-vsf1(n,2))<<endl;
	fmnm<<" 2 "<<1921+n<<" 2 1 1 "<<exploit_m2(1,n)<<" "<<vsm2(n,1)<<" "<<exploit_m2(1,n)*(-
(log(vsm2(n,1))))/(1-vsm2(n,1))<<endl;
	fmnm<<" 2 "<<1921+n<<" 2 1 2 "<<exploit_m2(2,n)<<" "<<vsm2(n,2)<<" "<<exploit_m2(2,n)*(-
(log(vsm2(n,2))))/(1-vsm2(n,2))<<endl;
	fmnm<<" 2 "<<1921+n<<" 2 2 1 "<<exploit_f2(1,n)<<" "<<vsf2(n,1)<<" "<<exploit_f2(1,n)*(-
(log(vsf2(n,1))))/(1-vsf2(n,1))<<endl;
	fmnm<<" 2 "<<1921+n<<" 2 2 2 "<<exploit_f2(2,n)<<" "<<vsf2(n,2)<<" "<<exploit_f2(2,n)*(-
(log(vsf2(n,2))))/(1-vsf2(n,2))<<endl;
	fmnm<<" 1 "<<1921+n<<" 1 1 1 "<<Cexploit_m1(1,n)<<" "<<vCsm1(n,1)<<" "<<Cexploit_m1(1,n)*(-
(log(vCsm1(n,1))))/(1-vCsm1(n,1))<<endl;
	fmnm<<" 1 "<<1921+n<<" 1 1 2 "<<Cexploit_m1(2,n)<<" "<<vCsm1(n,2)<<" "<<Cexploit_m1(2,n)*(-
(log(vCsm1(n,2))))/(1-vCsm1(n,2))<<endl;
	fmnm<<" 1 "<<1921+n<<" 1 2 1 "<<Cexploit_f1(1,n)<<" "<<vCsf1(n,1)<<" "<<Cexploit_f1(1,n)*(-
(log(vCsf1(n,1))))/(1-vCsf1(n,1))<<endl;
	fmnm<<" 1 "<<1921+n<<" 1 2 2 "<<Cexploit_f1(2,n)<<" "<<vCsf1(n,2)<<" "<<Cexploit_f1(2,n)*(-
(log(vCsf1(n,2))))/(1-vCsf1(n,2))<<endl;
	fmnm<<" 1 "<<1921+n<<" 2 1 1 "<<Cexploit_m2(1,n)<<" "<<vCsm2(n,1)<<" "<<Cexploit_m2(1,n)*(-
(log(vCsm2(n,1))))/(1-vCsm2(n,1))<<endl;
	fmnm<<" 1 "<<1921+n<<" 2 1 2 "<<Cexploit_m2(2,n)<<" "<<vCsm2(n,2)<<" "<<Cexploit_m2(2,n)*(-
(log(vCsm2(n,2))))/(1-vCsm2(n,2))<<endl;
	fmnm<<" 1 "<<1921+n<<" 2 2 1 "<<Cexploit_f2(1,n)<<" "<<vCsf2(n,1)<<" "<<Cexploit_f2(1,n)*(-
(log(vCsf2(n,1))))/(1-vCsf2(n,1))<<endl;
	fmnm<<" 1 "<<1921+n<<" 2 2 2 "<<Cexploit_f2(2,n)<<" "<<vCsf2(n,2)<<" "<<Cexploit_f2(2,n)*(-
(log(vCsf2(n,2))))/(1-vCsf2(n,2))<<endl;
	}
	}

FUNCTION void calculate_reference_points(int reg)
	//reference points based on MSY
	//MSY= ( rK / (z+1)^(1/z) ) * ( z/(z+1) )
	//not really SSN, doing total pop instead; adult females get almost wiped out, with a decade of juveniles
behind them, giving ridiculous r proxies
	dvector SSN(1,nobs);
	//Assuming the maximum population estimate represents K
	if(reg==2)SSN=value(extract_row(CN_f1,2)(1,nobs))+value(extract_row(CN_f1,1)(1,nobs))+value(extract_row(CN_
m1,2)(1,nobs))+value(extract_row(CN_m1,1)(1,nobs));
	if(reg==1)SSN=value(extract_row(N_f1,2)(1,nobs))+value(extract_row(N_f1,1)(1,nobs))+value(extract_row(N_m1,
2)(1,nobs))+value(extract_row(N_m1,1)(1,nobs));
	//Using estimates of K from surplus production models; have to rerun for each assumed r value
(.042,.052,.062)
	//if(reg==2)SSN=874*1000000;
	//if(reg==1)SSN=1475*1000000;
	//if(reg==2)SSN=940*1000000;
	//if(reg==1)SSN=1862*1000000;
	//if(reg==2)SSN=991*1000000;
	//if(reg==1)SSN=1948*1000000;
	dvector Nvec(1,nobs);
	//Assuming the shape of a density dependent population growth curve as z=1,2,3.
	//Increase this if we think density dependence would only start to kick in at higher densities.
	double Zlog=2.0; //total biomass
	//double Zlog=1.71; //SSB
	//Estimating the intrinsic rate of population growth, r, as the highest predicted
	// inter-year overall population growth plus r*10%.
	//Range r+(r*.025) to r+(r*.125) to test sensitivity.
	double Rbase=0.0;
	double Rnow=0.0;
	double No=0.0;
	double Nt=0.0;
	double MaxNt=max(SSN);
	double topbit;
	double botbit;
	double minbase;
	double minres;
	//finding the max r suggested by inter-year variability; compromised by association with maxed theta and
pupping
	for (int y=1; y<=nobs; y++) {
	//Using total abundance (allows for survey-only metric without rerunning the model)
	//Nvec(y)=value(Im_mj(y)+Im_ma(y)+Im_fj(y)+Im_fa(y));
	//Using SSN (have to run the model)
	Nvec(y)=SSN(y);
	if(y>1) Rnow=Nvec(y)/Nvec(y-1);
	if(Rnow>Rbase) {
	Rbase=Nvec(y)/Nvec(y-1);
	No=Nvec(y-1);
	Nt=Nvec(y);
	}
	}
	double rirg=log(Rbase+(Rbase*0.1));
```

```
    //instead of deriving r as above, just use a range based on more data-rich modelling
    rirg=0.017;
    rstep.initialize();
    zstep.initialize();
    msystep.initialize();
    bmsystep.initialize();
    kstep.initialize();
    fmsystep.initialize();
    double K;
    double CarCap;
    //homespun minimizer for carrying capacity
    //flooring Bmsy/K at 0.5
    double rstart=rirg-0.005;
    for (int r=1; r<=10; r++) {
    rstart=rstart+0.005;
    rstep(r)=rstart;
    zstep(r)=2.0;
    topbit = No*pow(2.71828,mfexp(rstep(r)));
    minbase=1000000000.0;
    for (int i=1; i<=100; i++) {
    if(reg==1)K=(MaxNt+((0.001*i)*MaxNt));
    if(reg==2)K=(MaxNt+((0.001*i)*MaxNt));
    botbit = 1.0 - No/K + No/K*pow(2.71828,mfexp(rstep(r)));
    minres=MaxNt-(topbit/botbit);
    if(fabs(minres)<minbase) {
    minbase=fabs(minres);
    kstep(r)=K;
    }
    }
    msystep(r)=(rstep(r)*(1.0-(1.0/Zlog)))*( pow((kstep(r)/Zlog),(1.0/(Zlog-1.0))) );
    bmsystep(r)=pow((kstep(r)/Zlog), (1.0/(Zlog-1.0)) );
    if(bmsystep(r)>0.0)fmsystep(r) = (msystep(r)/1.0)/bmsystep(r);
    }
    //centre r on a plausible mean (.04)
    double zstart=1.95; //SSB
    for (r=11; r<=20; r++) {
    rstep(r)=0.042;
    zstart=zstart+0.01;
    zstep(r)=zstart;
    topbit = No*pow(2.71828,mfexp(rstep(r)));
    minbase=1000000000.0;
    for (int ii=1; ii<=100; ii++) {
    if(reg==1)K=(MaxNt+((0.001*ii)*MaxNt));
    if(reg==2)K=(MaxNt+((0.001*ii)*MaxNt));
    botbit = 1.0 - No/K + No/K*pow(2.71828,mfexp(rstep(r)));
    minres=MaxNt-(topbit/botbit);
    if(fabs(minres)<minbase) {
    minbase=fabs(minres);
    kstep(r)=K;
    }
    }
    msystep(r)=(rstep(r)*(1.0-(1.0/zstep(r))))*( pow((kstep(r)/zstep(r)),(1.0/(zstep(r)-1.0))) );
    bmsystep(r)=pow((kstep(r)/zstep(r)), (1.0/(zstep(r)-1.0)) );
    //if(bmsystep(r)>0.0)fmsystep(r) = rstep(r)*(1.0-(1/zstep(r))); //checking, same answer as below
    if(bmsystep(r)>0.0)fmsystep(r) = (msystep(r)/1.0)/bmsystep(r);
    }


GLOBALS_SECTION
    #include <time.h>
    #include <admodel.h>
    #include <iostream>
  #include <fstream>
  #include <iomanip>
  #include <string>
 adstring_array regfile_name(1,10);
 adstring_array region_name(1,10);
 adstring_array survey_name(1,20);
 adstring_array out_file_names(1,100);
 dvector param_values(1,300);
 dvector param_active(1,300);
 adstring_array param_hdrs(1,300);
    time_t start,finish;
    long hour,minute,second;
    double elapsed_time;

 int icount=0;
 long int iseed=33579;
 double pibit=0.918939;
 ofstream projpopout("projpop.cha",ios::trunc);
 ofstream totprojpopout("totprojpop.cha",ios::trunc);


 //From Steve Martell
```

```
void function_minimizer::mcmc_eval(void)
{
        // |----------------------------------------------------------------------------|
        // | Added DIC calculation.  Martell, Jan 29, 2013                              |
        // |----------------------------------------------------------------------------|
        // | DIC = pd + dbar
        // | pd   = dbar - dtheta  (Effective number of parameters)
        // | dbar    = expectation of the likelihood function (average f)
        // | dtheta = expectation of the parameter sample (average y)

  gradient_structure::set_NO_DERIVATIVES();
  initial_params::current_phase=initial_params::max_number_phases;
  uistream * pifs_psave = NULL;

#if defined(USE_LAPLACE)
#endif

#if defined(USE_LAPLACE)
    initial_params::set_active_random_effects();
    int nvar1=initial_params::nvarcalc();
#else
  int nvar1=initial_params::nvarcalc(); // get the number of active parameters
#endif
  int nvar;

  pifs_psave= new
    uistream((char*)(ad_comm::adprogram_name + adstring(".psv")));
  if (!pifs_psave || !(*pifs_psave))
  {
    cerr <<"Error opening file "
            <<(char*)(ad_comm::adprogram_name + adstring(".psv"))
       <<endl;
    if (pifs_psave)
    {
      delete pifs_psave;
      pifs_psave=NULL;
      return;
    }
  }
  else
  {
    (*pifs_psave) >>nvar;
    if (nvar!=nvar1)
    {
      cout <<"Incorrect value for nvar in file "
           <<"should be " <<nvar1 <<" but read " <<nvar <<endl;
      if (pifs_psave)
      {
        delete pifs_psave;
        pifs_psave=NULL;
      }
      return;
    }
  }

  int nsamp = 0;
  double sumll = 0;
  independent_variables y(1,nvar);
  independent_variables sumy(1,nvar);

  do
  {
    if (pifs_psave->eof())
    {
      break;
    }
    else
    {
      (*pifs_psave) >>y;
      sumy = sumy + y;
      if (pifs_psave->eof())
      {
        double dbar = sumll/nsamp;
        int ii=1;
        y = sumy/nsamp;
        initial_params::restore_all_values(y,ii);
        initial_params::xinit(y);
        double dtheta = 2.0 * get_monte_carlo_value(nvar,y);
        double pd     = dbar - dtheta;
        double dic    = pd + dbar;
        double dicValue     = dic;
        double dicNoPar     = pd;

        cout<<"Number of posterior samples    = "<<nsamp    <<endl;
```

```
                 cout<<"Expectation of log-likelihood  = "<<dbar      <<endl;
                 cout<<"Expectation of theta           = "<<dtheta    <<endl;
                 cout<<"Number of estimated parameters = "<<nvar1     <<endl;
                     cout<<"Effective number of parameters = "<<dicNoPar <<endl;
                     cout<<"DIC                            = "<<dicValue <<endl;
                 break;
               }
               int ii=1;
               initial_params::restore_all_values(y,ii);
               initial_params::xinit(y);
               double ll = 2.0 * get_monte_carlo_value(nvar,y);
               sumll    += ll;
               nsamp++;
               // cout<<sumy(1,3)/nsamp<<" "<<get_monte_carlo_value(nvar,y)<<endl;
             }
           }
           while(1);
           if (pifs_psave)
           {
             delete pifs_psave;
             pifs_psave=NULL;
           }
           return;
         }


TOP_OF_MAIN_SECTION
     time(&start);
  arrmblsize=3000000;
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(1500000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(2000000);
  gradient_structure::set_MAX_NVAR_OFFSET(3500);
  //only need this for saving mcmc peojection results
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(4000);
RUNTIME_SECTION
  maximum_function_evaluations  15000,50000,50000,50000,200000,200000,200000
  //quick version (no waiting for convergence) to troubleshoot reference points
  //maximum_function_evaluations  50,50,50,50,100,100,100
 //convergence_criteria default = .0001; use .000001 if not getting Hessian; use 0.1 to expedite earlier stages
  convergence_criteria .000001, .000001, .000001, .000001, .000001, .000001, .000001, .000001, .000001,
.000001, .000001

FINAL_SECTION
     time(&finish);
     elapsed_time=difftime(finish,start);
     hour=long(elapsed_time)/3600;
     minute=long(elapsed_time)%3600/60;
     second=(long(elapsed_time)%3600)%60;
     cout<<"*********************************************"<<endl;
     cout<<"--Start time: "<<ctime(&start)<<endl;
     cout<<"--Finish time: "<<ctime(&finish)<<endl;
     cout<<"--Runtime: ";
     cout<<hour<<" hours, "<<minute<<" minutes, "<<second<<" seconds"<<endl;
     cout<<"*********************************************"<<endl;
```